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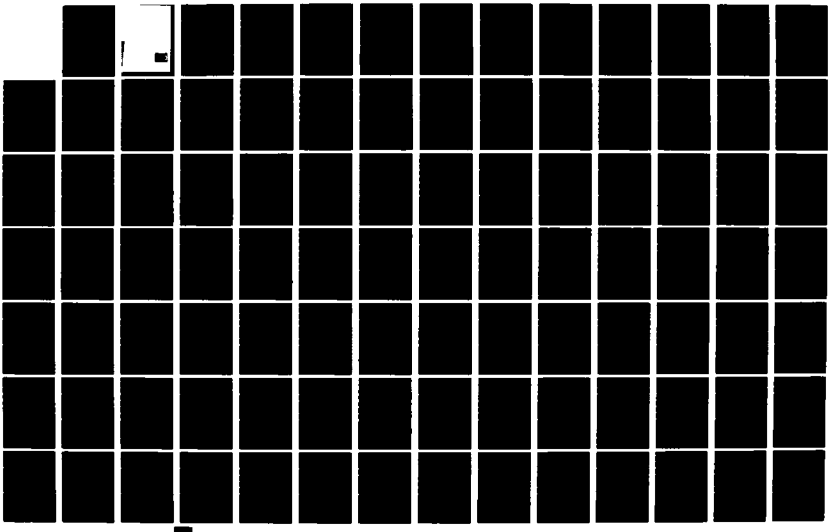

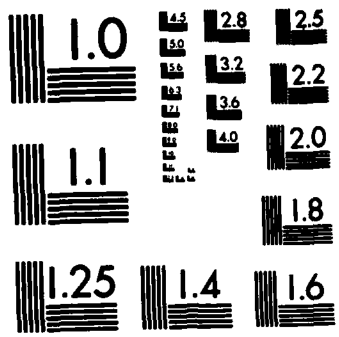

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This report summarizes field investigations conducted at seven reservoirs in 1979 and 1980 to determine the effect of reservoir releases on tailwater biota. The study sites differ greatly in project purpose, depth of water release from the reservoir, and location and are representative of many U. S. Army Corps of Engineers reservoirs throughout the United States.

Studies were conducted in tailwaters below both flood-control and peaking

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hydropower projects. Effects of reservoir discharge were most evident near the dams where environmental stress was most severe; farther downstream the effects were moderated. The invertebrate and fish communities in tailwaters were affected most by the temperature, volume, and timing of the discharges. High levels of iron and manganese occurred in most tailwaters, but their effects on invertebrates and fish were not addressed in this study.

The numbers of invertebrate and fish species were largest in tailwaters of flood-control projects with warmwater release and smallest in tailwaters of large hydropower projects. Invertebrate populations were seasonally more stable, although less diverse, in tailwater of hydropower projects than in tailwaters of flood-control projects. The uniform operation of the hydropower projects provided a relatively constant downstream environment for the few species present. Periodic flood discharges in the tailwaters of flood-control projects severely altered the tailwater environment and disrupted the invertebrate community.

Fish were most abundant in tailwaters of flood-control projects with warmwater release and least abundant in tailwaters of large peaking hydropower projects. Sunfishes, suckers, and catfishes were most important in tailwaters of flood-control projects; stocked trout provided the major fishery in the cold tailwaters of deep-release hydropower projects. Fish populations in the warmwater tailwaters were most similar to those in natural streams and were apparently least affected by dam operations. Fishes in cold tailwaters of deep-release hydropower projects were most affected by dam operations. The occurrence of diverse habitats in tailwaters (backwaters, deep pools, fallen trees, and large boulders) may moderate the effects of dam operations on both invertebrates and fish.

PREFACE

This report was prepared by the East Central Reservoir Investigations (ECRI), National Reservoir Research Program (NRRP), U. S. Fish and Wildlife Service, Bowling Green, Ky., with the assistance of the Environmental Laboratory (EL), U. S. Army Engineer Waterways Experiment Station (WES). This study forms part of the Environmental and Water Quality Operational Studies (EWQOS), Task IIB, Guidelines for Determining Reservoir Releases to Meet Environmental Quality Objectives. The EWQOS Program is sponsored by the Office, Chief of Engineers, and is assigned to WES under the management of EL.

This report was written by Messrs. Charles H. Walburg, Jerry F. Novotny, Kenneth E. Jacobs, and William D. Swink of ECRI. Mr. Walburg is the Chief of ECRI, and Mr. Robert M. Jenkins is the Director of the NRRP. The field studies on Barren River and Green River tailwaters and headwaters were conducted by Terry M. Campbell and Messrs. Jacobs, Novotny, Swink, and Walburg. Other NRRP biologists who conducted field studies, supplied necessary data, and reviewed this report were Mr. Richard L. Jones, Beaver tailwater; Mr. Hugh Barwick, Mr. Patrick L. Hudson, Ms. Susan J. Nichols, and Mr. James L. Oliver, Hartwell tailwater; and Messrs. Richard A. Frietsche and Stephen B. Smith, Pine Creek, Gillham, and Greeson tailwaters.

This report was prepared under the direct supervision of Dr. John M. Nestler, EL, WES, and the general supervision of Mr. Aaron B. Stein, Acting Chief, Water Quality Modeling Group, EL; Mr. Donald L. Robey, Chief, Ecosystem Research and Simulation Division, EL; and Dr. John Harrison, Chief, EL. Dr. Jerome L. Mahloch was Program Manager, EWQOS.

Commander and Director of WES during this study and the preparation of this report was COL Tilford C. Creel, CE. Technical Director was Mr. Fred R. Brown.

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CONTENTS

EFFECTS OF RESERVOIR RELEASES ON WATER QUALITY,

MACROINVERTEBRATES, AND FISH IN TAILWATERS:

FIELD STUDY RESULTS

PART I: INTRODUCTION

1. The U. S. Army Corps of Engineers (CE) operates reservoir projects to meet downstream environmental quality objectives consistent with authorized project purposes. However, present methods for determining the quality, quantity, and timing of reservoir releases necessary to maintain the tailwater ecosystem are inadequate because knowledge of project impacts is incomplete and the environmental requirements of many tailwater biota are poorly known. Consequently, the degree to which modifications in flow, temperature, dissolved gases, and other water quality characteristics associated with reservoir releases affect the composition and abundance of aquatic organisms in tailwaters is not readily predictable.

2. To better understand the effects of reservoir releases on the tailwater environment, the CE entered into a cooperative study agreement with the National Reservoir Research Program, U. S. Fish and Wildlife Service. The resulting research program was designed to develop and evaluate environmental criteria and operational methods that maintain desirable downstream aquatic habitat and associated biota. The study began with a comprehensive literature review (Walburg et al. 1981a, 1981b) and included a 2-year monitoring effort supplemented with short-term studies.

3. This report summarizes two years of field investigation of water quality, macroinvertebrates, and fish at seven CE reservoirs. Included were two flood-control reservoirs with warmwater releases that maintain reproducing warmwater tailwater fish populations (Pine Creek Lake and Gillham Lake); two flood-control reservoirs with coldwater releases that maintain put-and-take trout fisheries in the tailwaters (Barren River Lake and Green River Lake); and three

deep-release peaking hydropower reservoirs (Beaver Lake, Hartwell Lake, and Lake Greeson). These sites vary greatly in project purpose, release depth, and location, and are representative of many CE reservoirs throughout the United States.

4. To more fully understand causal relations between project operation and conditions in the tailwaters, water quality studies were conducted in both the reservoir and the tailwater. Macroinvertebrates and fish were collected in tailwaters to determine species occurrence and abundance in relation to operation of flood-control and hydropower projects. Studies were also conducted in the river above Barren River Lake and Green River Lake to determine differences between biota in natural streams and those in tailwaters.

5. This investigation was conducted in 1979 and 1980; all seven projects were studied in 1979, but Lake Greeson was excluded in 1980.

PART II: DESCRIPTION OF PROJECTS AND SAMPLING STATIONS

6. The seven projects investigated represent four widely different geographic regions. Pine Creek, Gillham, and Greeson reservoirs are between the mountains and lowlands in southeastern Oklahoma and central Arkansas; Barren and Green reservoirs are in the rolling hills of south-central Kentucky; Beaver Reservoir is in the Ozark region of northwestern Arkansas; and Hartwell Reservoir is in the piedmont area along the border of Georgia and South Carolina. Locations of reservoirs and sampling stations are shown in Appendix A.

7. Station location within tailwaters was generally determined by access. Station 1 was within 1.6 km of the dams; station 2, 2.1 to 10.5 km below the dams; and station 3, 12.1 to 22.5 km below the dams. The exception was Beaver tailwater where the station farthest downstream (station 4) was 5.5 km below the dam. A headwater station (station A) was located above both Barren and Green reservoirs.

8. Physical and operational characteristics of the four flood-control reservoirs (Pine Creek, Gillham, Barren, Green) were similar (Table 1). All four dams released water through multi-level bypasses located at two or nine different elevations. Flows greater than the maximum capacity of the bypasses were released through floodgates located near the bottom of the dams. All four flood-control projects had tailwaters with established minimum flows ranging from 0.8 to 2.4 m^3/sec. Large-volume flows, which were associated with heavy rainfall, occurred during all seasons, and lasted from a few days to over a month. The size, substrate, and topography of tailwaters below flood-control projects differed from site to site. Detailed descriptions of the sampling stations in each tailwater and Barren and Green reservoir headwaters illustrate the differences in surface area, depth, substrate, and physiography (Appendix B, Tables B1 through B4). The station 1 sampling location in Barren tailwater was moved closer to the dam in 1980. Cover and habitat conditions at both locations were similar.

Table 1

Description of the Seven Reservoirs Mentioned in This Report

Reservoir, River, State, and Date of Closure	Project Purposes	Dam Construction and Release Type	Surface Area (hectares) and Elevation (metres above msl) at Seasonal or Power Pool	Maximum Discharge Capacity (m^3/sec) at Seasonal or Power Pool	Elevation of Release Outlet (metres above msl)	Minimum Established Discharge (m^3/sec)	Storage Ratio*
Pine Creek Lake, Little River, Oklahoma June 1969	Flood control, water supply	Earth-fill, multi-level outlet (2 levels)	2,025/135.3	226.4 (flood gate) 10.5 (bypass)	117.1 129.0; 123.8	1.8	0.08
Gillham Lake, Cossatot River, Arkansas May 1975	Flood control, water supply	Earth-fill, multi-level outlet (2 levels)	555/153.1	84.9 (flood gate) 4.2 (bypass)	133.3 148.5; 144.0	0.8	0.07
Barren River Lake, Barren River, Kentucky March 1964	Flood control, recreation	Earth-fill, multi-level outlet (2 levels)	4,047/168.0	291.5 (flood gate) 14.2 (bypass)	146.0 162.0; 156.0	2.1	0.24
Green River Lake, Green River, Kentucky February 1969	Flood control, recreation	Earth-fill, multi-level outlet (9 levels)	3,322/206.0	263.2 (flood gate) 14.4 (bypass)	185.0 203.0 - 192.0	2.4	0.28
Beaver Lake, White River, Arkansas December 1963	Hydropower, flood control, water supply	Concrete-gravity, deep-release outlet	11,420/341.4	320.6 (2 generators) 0.6 (house generator)	307.0 - 299.3	0.8 (house generator and leakage)	1.69
Hartwell Lake, Savannah River, Georgia/South Carolina February 1961	Hydropower, flood control, recreation	Concrete-gravity, deep-release outlet	22,640/201.2	665.4 (4 generators)	181.4 - 160.9	3.0 (leakage)	0.83
Lake Greeson, Little Missouri River, Arkansas December 1949	Hydropower flood control	Concrete-gravity, deep-release outlet	2,940/167.1	92.1 (3 generators) 169.9 (2 flood gates)	146.4 133.2	0.3 (leakage)	0.77

*Source, Leidy and Jenkins (1977).

9. Characteristics of the three peaking hydropower projects were generally similar, except for the relative size of the reservoirs and their discharge capacity (Table 1). Water was discharged 20 to 40 m below the reservoir surface, and releases reflected demand for electricity, usually peaking during weekday, daylight hours. During nongeneration periods, project leakage provided the only water to the tailwaters. Detailed descriptions of the sampling stations in these tailwaters show differences in surface area, depth, substrate, and physiography (Appendix B, Tables B5 through B7).

10. Rainfall was above average over the southeastern United States in 1979, but was below average in 1980. The difference in between-year precipitation resulted in higher reservoir discharges in 1979 than in 1980. Minimum flows rarely occurred in Barren and Green tailwaters in 1979, whereas they were common in 1980. Peaking flows were high over a more extended period in the hydropower reservoirs in 1979 than in 1980. Beaver tailwater was inundated for much of 1979 because of the high level of the immediate downstream reservoir (Table Rock). In 1980, the water level of Table Rock Lake was low and the flowing portion of Beaver tailwater extended from 16 to 19 km below the dam.

PART III: METHODS

Water Quality

11. Water quality samples were taken seasonally at all sample sites in 1979 and 1980 (Table 2). All collections were taken during low-flow periods. Temperature and dissolved oxygen profiles were obtained for each reservoir to supplement tailwater water quality data. In addition to the above program, 1-ℓ water samples were taken weekly (June to November) in 1980 from immediately below the dam in Barren and Green tailwaters to determine changes in iron, manganese, and ammonia concentrations. Weekly samples were taken at prevailing flows.

12. Alkalinity, ammonia, conductivity, total iron, total manganese, dissolved oxygen, pH, sulfides, temperature, and particulate matter were determined using procedures described in Standard Methods (American Public Health Association et al., 1976). Particulate matter was subdivided into the following fractions: coarse particulate organic matter (CPOM), coarse particulate inorganic matter (CPIM), fine particulate organic matter (FPOM), fine particulate inorganic matter (FPIM), and total dissolved solids (TDS). Equipment and methods used to obtain and analyze the samples varied among tailwaters (Appendix C, Tables C1 through C4).

13. Coarse particulate matter (CPM) was determined by filtering 10 to 30 litres of water through an 0.08-mm-mesh net. Material retained on the net was dried to a constant weight at 60°C for 24 hours. Fine particulate matter (FPM) was determined by filtering a 1-ℓ subsample of the CPM filtrate through a glass-fiber filter and drying at 60°C for 24 hours. Inorganic portions of coarse and fine particulate matter were determined by ashing the dried samples at 550°C for 20 minutes. CPOM and FPOM were determined by subtracting the inorganic portions from the total CPM or FPM, respectively. TDS content was determined by evaporating 100 to 500 ml of FPM filtrate to a constant weight at 103-105°C.

Table 2

Months When Water Quality (W), Invertebrate (I), and Electrofishing (F) Samples Were Taken at Seven Reservoir Projects, 1979 and 1980

Date	Reservoir						
	Pine Creek	Gillham	Barren	Green	Beaver	Hartwell	Greeson
1979							
April	W I F					W I F	
May			I	W I F	F*	W I* F	W I F**
June	W I F	W I F†	W I F	W F	W†† F†	F	W I F*
July		W I F†			W†† F††	W I F§	W I F
August	W I F		W I F	W I F		W F†	
September	W I F	W I F	W F††	I		W I* F	W I F
October		W I F	W I F	W I F	W I F	W I* F	W I F
November	W I F					W I§	
1980							
January					I F		
February	W I F	W I F			W*	W I F	
April			I F	W F	W I F		
May			W F	I	W	W I F	
June	W I F	W F	W I F	I F	W I F		
July	I	W I F	F			W I F	
August	W I F	W	W I F	W I F			
September	W F	W I F	F		W I F		
October			W I F	W I F	W	W I F	
December					W		

Note: Type of sample taken at each station is indicated in Appendix B unless otherwise noted as follows:

- * Sampled only station 2.
- ** Sampled only station 1.
- † Sampled only station 3.
- †† Sampled only stations 2 and 3.
- § Sampled only stations 1 and 2.

14. Mean daily releases from the flood-control reservoirs and daily maximum and minimum releases from the hydropower reservoirs were obtained from either the U. S. Geological Survey (USGS) or the CE. Maximum daily water temperatures in Barren and Green tailwaters were obtained from USGS gauge records and in Hartwell tailwater from CE recording monitors.

Macroinvertebrates

15. Several methods were used to collect macroinvertebrates because of differences in habitat among the seven tailwaters (Table 3). After evaluation of initial field sampling, only the methods that proved reliable in a particular tailwater were continued. Seasonal samples were taken at each project except Barren and Green, where high flows prevented winter sampling. Months when invertebrate samples were collected at each project are shown in Table 2. All samples were taken during low-flow periods.

16. Pine Creek and Gillham tailwaters were sampled with drift and Hess samplers. Three stations (1, 2, and 3) were sampled in each tailwater in 1979 but only stations 1 and 3 were sampled in 1980. Drift nets were used to collect organisms suspended in the flowing water. These samplers consisted of a plexiglass frame with a 0.01-m^2 opening flared back to 0.1 m^2. The collecting net was 1-m long with 0.50-mm mesh. The water volume that passed through the sampler was estimated by multiplying the flow velocity adjacent to the sampler by time and size of opening. Samplers were placed below a riffle at each station and were left in the stream overnight. The Hess sampler was used to sample the benthic community in riffle substrates. Two replicates were collected at each station during each sampling period. The sampler was placed in 10 to 40 cm of water, and the stream bottom was disturbed to a depth of about 10 cm. Displaced organisms were flushed into the collecting net (0.25-mm mesh).

17. Barren and Green tailwaters were sampled with drift and Hess and Hester-Dendy plate samplers. Collections were made from three

Table 3

Methods Used to Sample Macroinvertebrates

Tailwater	Sampling Method	1979	1980
Pine Creek, Gillham	Drift	X	X
	Hess	X	X
Barren, Green*	Drift	X	X
	Hess	X	X
	Hester-Dendy	X	X
Beaver	Suction sampler**	X	X
Hartwell	Hess	X	X
	Hester-Dendy	X	
	Core	X	X
	Substrate sampler	X	X
Greeson	Hess	X	

*All sample methods used in tailwaters were also used to collect samples in the headwater stream above both reservoirs in 1980.

**This sample method yields results similar to the Hess (number of organisms per unit area of substrate).

stations (1, 2, and 3) in 1979, and from stations 1 and 3 plus above-reservoir station A in 1980. Sampling methods for drift and Hess samplers were similar to those described for Pine Creek and Gillham, except that drift samplers were left in the stream for 24-hours and three replicate Hess samples were collected at each station. Hester-Dendy plate samplers provided a uniform substrate and a measured area for invertebrate colonization. Paired samplers were placed in run sections, 0.5 to 1.0 m deep (at low flow), where they remained for at least 4 weeks before removal. Plates for the Hester-Dendy sampler were made from a 0.64-cm plexiglass.

18. Macroinvertebrate samples were collected in Beaver tailwater at three sites (stations 1, 2, and 4) during both years with a suction sampler after other methods proved unreliable. Three replicate

samples were collected from riffles at each of the sampling stations. Each sample was pumped from a 0.16-m^2 area of stream bottom. This sampling method gave results comparable to those given by the Hess sampler (e.g., number of organisms per measured area of stream bottom).

19. Hartwell tailwater samples were collected with Hess, Hester-Dendy, and core samplers, and a specialized substrate sampler. Hess samples were collected at all stations in July 1979 and in May, July, and October 1980. Hester-Dendy samplers were used at each station during April through November 1979; paired samples were retrieved at 6-week intervals. Two replicate core samples were collected with a sampler made of PVC pipe, 10.1 cm in diameter, in pools and riffles and along mud banks during July 1979 and May, July, and October 1980. The specialized substrate sampler was used in July 1979 and February, May, July, and October 1980 to obtain invertebrate standing crop estimates from the boulder-bedrock substrate in Hartwell tailwater. This sampler consisted of a round, tubelike enclosure (5.4 cm in diameter) which was held firmly against the substrate while the enclosed area was scraped and particles were removed by suction.

20. In Greeson tailwater, macroinvertebrates were sampled with a Hess sampler in 1979.

21. All invertebrate samples were preserved in 10 percent formalin and returned to the laboratory for sorting and enumeration. Organisms were identified to the lowest practicable taxon based on man-hours available for identification; most were identified to order or family. Biomass estimates were obtained by direct dry weight analysis or by applying a predetermined length-weight relation to the number and taxa data. No corrections were made for preservative.

22. Hess sample data were used for comparison of taxonomic composition, total numbers, biomass, total taxa, and community diversity among tailwaters, because it was the only sample method common to all tailwaters except Beaver. Suction-sampler data were used for Beaver, since this sampler provided information similar to that obtained with the Hess. Shannon-Weaver diversity indices (Lloyd, Zar, and Karr 1968) were calculated.

23. An ordination was used to compare macroinvertebrate communities in the Barren and Green tailwaters with those of the headwater streams (Hocutt 1975). These were the only tailwaters where ordination analysis was feasible because there were no reference stations (above the reservoir) at the other study locations. To complete this analysis, the number of taxa was plotted against the total number of organisms for each Hess sample. The plot was further divided into four quadrants, using mean taxa and mean total numbers from station A as the boundaries. The distribution of the data points within the four quadrants provides an insight into the environmental factors limiting the macroinvertebrate community at each of the stations. The following is an explanation of the quadrant locations:

Quadrant I--community is affected by species-selective stress--numbers of taxa are reduced, whereas the total number of tolerant organisms increases: factors affecting stream environment are limiting to some species.

Quadrant II--standing crop and niche partitioning is maximized--numbers of taxa and organisms both increase: most like unregulated stream community.

Quadrant III--community is affected by sublethal (or toxic) perturbations--numbers of taxa and organisms both decrease: least like an unregulated stream community.

Quadrant IV--community is affected by nonselective stress--total numbers are reduced, but the number of taxa present remains unaffected: moderately stressed unregulated stream community.

24. Differences in macroinvertebrate communities in Barren and Green tailwaters and above reservoir stations were best summarized by comparing the distribution of functional feeding groups. Aquatic insects collected at the three stations in 1980 were divided into four main categories--collectors (C), predators (P), shredders (SH), and scrapers (SC)--based on classifications by Merritt and Cummins (1978).

Fish

25. All stations were sampled with similar electrofishing gear; however, dates of sampling varied among projects because of differences in local weather and water-release schedules (Table 2). All samples were taken during low-flow periods. A boat-mounted electroshocker was used to electrofish a complete circuit of each sampling station, including all habitats (pools, riffles, backwaters, fallen trees, etc.). Riffles too shallow for electroshocker operation (less than 0.3 m deep) were not sampled. Direct current (1.5-4.0 amperes) was used to sample fish at all stations except Beaver tailwater, where alternating current was used. Fish collected were held in a live-box until they were measured and weighed, and then were returned to the sample area. Occasionally, small fish captured in large numbers were counted and weighed together to hasten their return to the stream. At Beaver tailwater, not all fish species electroshocked were captured; catch rates were calculated only for species that were collected at each fishing. Night sampling was conducted at Hartwell and Beaver tailwaters; other projects were sampled during daylight.

26. Catch rates (fish/hour and biomass/hour) for fish species collected at each project in 1979 and 1980 were calculated from the catches by electrofishing and shocking time; the data for six of the reservoirs are included in Appendix D. Since catch rates at each tailwater were generally similar between years, data were combined. Estimates of relative abundance and distribution of fish were derived from the electrofishing catch rates.

27. Angler surveys were conducted during 1979 and 1980 at Pine Creek, Gillham, Greeson, Barren, Green, and Beaver reservoirs and their tailwaters by state agencies--i.e., the Arkansas Game and Fish Resources at Greeson, Gillham, and Beaver reservoirs; the Kentucky Department of Fish and Wildlife Resources at Barren and Green reservoirs; and the Oklahoma Department of Wildlife Conservation at Pine Creek Reservoir. A stratified random-sampling design was used to estimate daytime angling effort from aerial angler counts and angler

success from angler interviews. These data were combined to estimate harvest.

28. Common and scientific names of fishes mentioned in this report are listed in Appendix E. Nomenclature follows Robins et al. (1980). Also included are estimates of relative abundance of species in each tailwater, based on catch by electroshocker.

PART IV: RESULTS

Water Quality

Pine Creek

29. Reservoir. Temperature and dissolved oxygen profiles exhibited similar patterns in 1979 and 1980 (Appendix F, Figure F1). The reservoir lacked a pronounced thermocline but temperature gradually decreased from surface to bottom (thermal gradient). A clinograde oxygen profile was observed in June and persisted throughout the summer in both years. Dissolved oxygen during both summers was consistently less than 1 mg/ℓ below a depth of 2 to 5 m.

30. Tailwater. Mean daily discharges in the spring were greater in 1979 than in 1980 (Appendix G, Figure G1). Discharges were reduced to the established minimum (1.8 m^3/sec) in mid-June 1979 and were maintained at that level for most of the summer and autumn. Substantial periods of minimum discharge occurred in 1980 during January, March, July, August, and September. In spite of the higher total discharge in 1979, the number of days of minimum flow was similar in both years.

31. Summer water temperatures at all three stations were usually between 25 and 30°C in both years (Table 4). Dissolved oxygen was above 5 mg/ℓ in all samples except that of August 1980 at station 3. Conductivity, which ranged between 29 and 65 μmhos/cm, did not appear to vary seasonally; however, readings at station 3 were typically higher. The pH levels in the tailwater were slightly higher in 1980 than in 1979, but this difference may be the result of a change in sampling methods. Alkalinities were consistently higher in 1980 than for comparable periods in 1979. Ammonia was low in all 1979 samples (<0.2 mg/ℓ), but exceeded 0.3 mg/ℓ in the August 1980 samples and reached 1.08 mg/ℓ and 0.71 mg/ℓ at stations 1 and 2, respectively, in September. Measurable sulfide was recorded only at station 1 in June, August, and September 1979 and in August 1980. During these periods, a strong sulfide odor was present below the outlet structure. Iron

Table 4

Water Quality Variables Measured in the Tailwater below Pine Creek Lake, 1979 and 1980

Date	Station	Temp. °C	DO mg/ℓ	Conductivity µmhos/cm	pH	Alkalinity mg/ℓ $CaCO_3$	Ammonia mg/ℓ	Sulfide mg/ℓ	Fe mg/ℓ	Mn mg/ℓ	CPIM mg/ℓ	CPOM mg/ℓ	FPIM mg/ℓ	FPOM mg/ℓ	TDS mg/ℓ
1979															
25 April	1	22.0	8.6	40	5.9	6.0	0.00	0.0	0.9	0.2	0.17	0.00	4.66	7.12	56.6
	2	19.5	7.9	37	6.0	8.0	0.00	0.0	0.5	0.2	0.10	0.08	7.55	2.34	69.4
	3	22.0	7.6	55	6.0	17.5	0.00	0.0	1.0	0.2	0.09	0.05	8.08	2.34	73.3
27 June	1	25.5	7.5	37	6.5	13.5	0.16	0.3	2.1	1.2	0.21	0.18	2.95	2.65	56.0
	2	22.7	6.6	46	6.0	9.0	0.08	0.0	1.6	0.7	0.05	0.09	1.70	2.40	56.1
	3	28.4	7.4	65	5.7	11.0	0.00	0.0	1.6	0.4	0.00	0.14	1.90	5.15	75.5
15 Aug.	1	27.0	7.5		5.7	12.5	0.19	0.3	2.9	1.4	0.37	0.05	4.72	0.83	14.6
	2	27.0	7.8	48	6.1	14.0	0.13	0.0	2.3	1.0	0.20	0.00	3.75	0.38	45.6
	3	27.5	5.6	61	6.0	12.7	0.00	0.0	2.1	0.7	0.05	0.06	4.00	0.64	
19 Sept.	1	24.5	6.7	42	5.8	9.0	0.06	0.3	2.4	0.5	0.15	0.21	2.30	1.60	43.4
	2	24.0	6.8	41	5.8	9.7	0.06	0.0	1.2	0.3	0.14	0.02	1.80	1.06	46.1
	3	22.6	6.4	45	5.8	9.0	0.01	0.0	1.0	0.3	0.28	0.11	2.50	2.60	60.8
6 Nov.	1	16.0	9.3	45	6.0	10.8	0.14	0.0	0.6	0.2	0.36	0.11	2.55	1.01	45.5
	2	14.5	9.3	43	6.1	17.8	0.08	0.0	0.5	0.2	0.12	0.08	1.75	0.85	42.8
	3	13.5	8.6	54	5.8	16.0	0.01	0.0	0.8	0.2	0.23	0.08	2.23	1.27	40.7
1980															
7 Feb.	1	9.0	11.8	41	6.2	10.9	0.31	0.0	0.6	0.1	0.00	0.13	3.80	2.00	39.8
	2	6.0	11.9	49	5.8	10.5	0.19	0.0	0.5	0.1	0.24	0.11	3.50	0.87	44.6
	3	5.8	11.3	53	5.8	16.5	0.22	0.0	0.8	0.2	0.34	0.96	3.60	1.30	55.6
17 June	1	27.0	7.9	29	6.5	16.0	0.03	0.0	0.2	0.0	0.63	0.11	1.80	2.80	49.9
	2	27.0	6.8	31	6.6	19.0	0.00	0.0	0.5	0.0	0.52	0.59	1.60	1.55	95.6
	3	30.0	7.3	44	6.4	25.5	0.01	0.0	0.5	0.0	0.64	0.28	8.30	6.20	
5 Aug.	1	27.0	5.7	49	6.5	30.0	0.34	0.6	1.9	1.4	0.65	0.51	1.49	0.96	50.3
	2	24.0	5.5	44	6.4	39.0	0.56	0.0	2.6	1.8	0.88	0.29	4.57	1.17	52.3
	3	29.0	4.8	51	6.5	29.0	0.30	0.0	1.4	0.9	0.41	0.21	4.88	1.90	53.6
9 Sept.	1	29.5	6.4	40	6.7	16.0	1.08	0.0	0.9	0.5	0.39	0.03	1.28	0.11	49.7
	2	27.0	5.8	45	6.7	14.5	0.71	0.0	0.7	0.4	0.09	0.06	0.36	0.37	54.4
	3	29.0	5.9	61	6.6	14.0	0.19	0.0	0.1	0.2	0.44	1.10	0.85	3.72	50.4

levels were higher in 1979 than in 1980; all 1979 summer samples were above 1.0 mg/ℓ, probably as a result of the lower reservoir release gate being open during most of the period (Appendix F, Figure F1). In 1980, iron levels were relatively high at all three stations, but exceeded 1.0 mg/ℓ only in the August sample. Manganese levels in the tailwater did not differ substantially between 1979 and 1980. Highest levels were observed in August of both years and exceeded 1.0 mg/ℓ at both stations 1 and 2. Analysis of particulate matter and total dissolved solids did not indicate any substantial differences between years or stations. Fine particulate matter, both organic and inorganic, made up the largest share of particulate matter in the system.

Gillham

32. Reservoir. Temperature changes from the reservoir surface to the bottom were more gradual in 1979 than in 1980, when a thermocline was observed in the June profile at a depth of about 4 m (Appendix F, Figure F2). A clinograde oxygen profile was observed by June in both years. Dissolved oxygen was consistently at or below 1 mg/ℓ in the lower levels of the reservoir from July through September. The profile taken 24 October 1979 indicated that the lake had become isothermal, but anaerobic conditions persisted below a depth of about 11 m.

33. Tailwater. Mean daily discharges were consistently higher in 1979 than in 1980 (Appendix G, Figure G2). Minimum established flow (0.8 m^3/sec) occurred infrequently during the summer of 1979 because storms were numerous. In 1980, spring discharges were lower than in 1979, and minimum flow was maintained from the end of June through September.

34. As judged by infrequent seasonal samples, tailwater temperatures appeared to be higher in 1980 than in 1979 (Table 5). Dissolved oxygen was consistently above 6.0 mg/ℓ at all stations in both years. Conductivity was between 30 and 48 μmhos/cm and did not vary substantially by station or season. The pH values were somewhat higher in 1980 than 1979, perhaps as a result of the change in sampling methods. Alkalinities were consistently higher throughout 1980 than

Table 5

Water Quality Variables Measured in the Tailwater below Gillham Lake, 1979 and 1980

Date	Station	Temp. °C	DO mg/ℓ	Conductivity µmhos/cm	pH	Alkalinity mg/ℓ $CaCO_3$	Ammonia mg/ℓ	Sulfide mg/ℓ	Fe mg/ℓ	Mn mg/ℓ	CPIM mg/ℓ	CPOM mg/ℓ	FPIM mg/ℓ	FPOM mg/ℓ	TDS mg/ℓ
1979															
12 June	1	20.0	8.8	30	6.0	7.0	0.00	0.00	0.4	0.1	0.00	0.10	4.83	1.46	107.4
	2	23.2	8.2	36	6.0	9.0	0.00	0.00	0.3	0.1	0.01	0.10	5.09	0.88	76.3
	3	26.0	9.4	43	5.8	7.5	0.00		0.3	0.1	0.00	0.06	3.51	1.38	97.3
25 July	1	25.5	7.7	40	6.6	10.7	0.00	0.26	0.6	0.4	0.09	0.05	5.10	1.10	31.8
	2	25.0	6.6	38	5.7*	14.0*	0.00	0.00	0.4	0.2	0.06	0.00	3.75	0.65	37.0
	3	27.0	7.0	48	6.6*		0.00	0.00	0.5	0.1	0.00	0.03	3.80	0.90	41.0
12 Sept.	1	26.5	6.8	40	5.8	10.8	0.14	0.16	1.0	0.4	0.12	0.02	2.45	2.02	43.9
	2	24.0	7.6	38	6.1	9.7	0.00	0.00	1.0	0.2	0.05	0.02	2.60	2.13	129.8
	3	26.0	7.4	42	6.2	12.0	0.00	0.00	1.3	0.3	0.09	0.00	2.55	2.13	50.8
24 Oct.	1	21.0	8.6	39	5.8	19.0	1.10	0.00	0.5	0.1	0.23	0.09	1.50	1.20	46.3
	2	19.0	8.7	42	5.2	25.0	0.04	0.00	0.3	0.2	0.22	0.08	2.55	1.00	37.6
	3	18.0	8.4	39	5.9	16.0	0.00	0.00	0.4	0.0	0.13	0.02	2.40	0.90	34.4
1980															
27 Feb.	1	8.0	11.5	34	6.2	7.8	0.00	0.00			0.09	0.06	3.51	1.38	34.9
	2	7.5	11.8	41	5.8	12.0	0.07	0.00			0.13	0.04	2.98	1.48	36.4
	3	7.0	10.8	32	5.8	15.0	0.03	0.00			0.11	0.02	2.34	1.27	40.6
11 June	1	25.5	7.4	30	6.6	20.0	0.00	0.00	0.3	0.1	0.03	0.00	1.80	3.20	35.6
	2	22.5	6.6	40	6.8	20.0	0.00	0.00	0.4	0.1	0.66	0.28	6.45	5.10	31.0
	3	27.0	8.0	39	6.6	23.0	0.05	0.00	0.5	0.1	0.79	0.00	0.00	3.00	60.0
9 July	1	29.0	6.6	30	6.1	19.0	0.03	0.00	0.3	0.1	0.12	0.02	2.10	1.00	29.4
	2	28.0	6.3	35	6.6	17.0	0.03	0.00	0.2	0.2	0.10	0.06	7.70	0.65	19.8
	3	32.0	5.9	39	6.8	19.0	0.05	0.00	0.2	0.2	0.16	0.05	5.40	0.30	38.5
26 Aug.	1	30.0	8.6	36	7.0	21.0	0.01	0.00	0.6	0.1	0.07	0.02	1.91	0.64	30.6
	2	30.0	7.7	32	6.9	23.0	0.00	0.00	0.6	0.1	0.01	0.04	5.00	1.62	35.4
	3	30.0	8.4	36	6.7	21.0	0.01	0.00	0.6	0.1			5.42	0.24	36.4
17 Sept.	1	29.0	7.8	42		18.2	0.00	0.00	0.2	0.2	0.13	0.07	1.27	1.49	42.9
	2	28.5	7.2	42	7.0	12.0	0.11	0.00	0.2	0.1	0.02	0.03	2.45	1.70	37.8
	3	26.5	6.2	42	6.8	15.6	0.07	0.00	0.3	0.2	0.20	0.34	4.26	1.17	36.7

*pH meter did not standardize.

1979, but were always less than 25.0 mg/ℓ. Ammonia remained below 0.2 mg/ℓ in all samples except at station 1 in October 1979, when it reached 1.1 mg/ℓ. Sulfide was detected only at station 1 in July and September 1979. Iron and manganese were both higher in 1979 than in 1980. Highest iron levels were recorded in September 1979 and were equal to or greater than 1.0 mg/ℓ at all stations. Manganese was also highest in September 1979, but did not exceed 0.4 mg/ℓ. Higher values of sulfide, iron, and manganese during summer 1979 were probably a result of all reservoir discharge being released from the lower release gate (Appendix F, Figure F2). Analysis of particulate matter and total dissolved solids did not yield any discernible patterns, either seasonally or by station. Most particulate matter consisted of fine inorganic and organic fractions.

Barren

35. Reservoir. The reservoir was thermally stratified by May of both 1979 and 1980 at a depth of 3 to 5 m (Appendix F, Figures F3 and F4). Thermal stratification was maintained from May through September in 1980. In 1979, large flood releases depleted the hypolimnion and disrupted the formation of the thermocline. By early September, the thermocline was replaced by a thermal gradient extending from the surface to the bottom. The reservoir became isothermal by 29 October of both years. A clinograde oxygen profile was observed by May and was maintained throughout the summer of both years. In 1979, the hypolimnion became anoxic in early June; in 1980, however, dissolved oxygen levels remained above 1 mg/ℓ until early July.

36. Tailwater. Mean daily discharge was substantially higher throughout 1979 than in 1980 (Appendix G, Figure G3). Minimum established flows (2.1 m^3/sec) were released only occasionally in 1979 and never for more than four consecutive days. In 1980, minimum flows were maintained throughout August and in parts of March, June, July, and September. Higher water temperatures were recorded in the tailwater in 1979 than in 1980 (Appendix G, Figure G3). Maximum temperatures above 24°C occurred on 25 days during the summer of 1979, but none were recorded in 1980. Temperatures exceeded 21°C for a similar number

of days during the summers of both years, regardless of the volume of discharge.

37. Seasonal dissolved oxygen concentrations were always greater than 5.0 mg/ℓ (Table 6). Conductivity was usually lowest at station 1 and increased downstream; values ranged from 170 to 255 μmhos/cm. The pH in Barren River was always above 6.7 and usually above 7.0; values were highest in summer. Alkalinities were lowest at station 1 and increased downstream. Highest levels were recorded in August and September 1979. Ammonia was detected in substantial quantities in September 1979 and in August and October 1980; concentrations were highest at station 1. Sulfides were not detected at minimum flow during 1979 or 1980. However, when large quantities of hypolimnial water were released, the odor of hydrogen sulfide was common in the tailwater near the dam. Higher levels of iron were recorded in 1980 seasonal samples than in 1979. Readings above 0.5 mg/ℓ were recorded at station 3 in May 1980 and at stations 1 and 3 in August 1980. Manganese was higher in the 1979 seasonal samples than in 1980. Values of 0.4 mg/ℓ were recorded at all three tailwater stations in early June 1979; 0.6 mg/ℓ was recorded at station 1 in September 1979. CPM levels (organic and inorganic combined) were highest in the spring of both years and declined during summer. FPIM levels were higher in 1980 than in 1979. FPOM levels were similar throughout 1979 and 1980, but a large increase was observed at all tailwater stations in August 1979. TDS values usually ranged from 70 to 150 mg/ℓ, but exceeded 220 mg/ℓ at all stations in late June 1979.

38. Ammonia, iron, and manganese concentrations were determined weekly (June to November) in Barren tailwater in 1980 (Figure 1). Ammonia exceeded 1.0 mg/ℓ periodically from the end of August through October. Iron concentrations exceeded 0.3 mg/ℓ in August and again in late October. Manganese values were consistently above 0.05 mg/ℓ from late June through October.

39. Headwater. Seasonal water samples were collected from Barren reservoir headwater (station A) only in 1980 (Table 6). Water temperatures ranged from a high of 23°C in August to a low of 12°C in

Table 6

Water Quality Variables Measured in the Tailwater below Barren River Lake, 1979 and 1980

Date	Station	Temp. °C	DO mg/ℓ	Conductivity μmhos/cm	pH	Alkalinity mg/ℓ $CaCO_3$	Ammonia mg/ℓ	Sulfide mg/ℓ	Fe mg/ℓ	Mn mg/ℓ	CPIM mg/ℓ	CPOM mg/ℓ	FPIM mg/ℓ	FPOM mg/ℓ	TDS mg/ℓ
1979															
4 June	1	17.0	8.4	175	6.8	71.4	0.00	0.0*	0.1	0.4	0.30	0.55	3.00	5.80	
	2	17.0	8.5	180	6.8	71.4	0.00	0.0	0.1	0.4			1.80	10.20	45.0
	3	18.0	8.2	185	6.9	74.6	0.00	0.0	0.2	0.4	0.70	2.35	4.50	16.80	85.0
16 June	1		8.0	170	7.1	69.3	0.00	0.0	0.0	0.1	0.33	0.65	2.50	4.00	245.0
	2	21.7	6.7	193	6.9	78.8	0.00	0.0	0.1	0.1	0.48	0.33	4.80	3.80	227.5
	3	21.5	7.2	205	6.9	90.3	0.00	0.0	0.1	0.1	0.45	0.75	2.00	6.00	247.5
2 Aug.	1	24.0	7.7		7.4	88.6	0.01	0.0	0.1	0.3	0.13	0.18	3.50	22.50	77.5
	2	23.0	5.9		8.3	109.3	0.01	0.0	0.1	0.2	0.10	0.00	2.50	21.00	125.0
	3	22.0	6.1		8.4	116.2	0.00	0.0	0.2	0.2	0.00	0.20	2.80	20.00	117.5
12 Sept.	1	24.0	7.1	220	7.4	91.3	0.20	0.0	0.2	0.6	0.13	0.08	3.00	2.50	110.0
	2	23.0	5.1	240	7.4	102.3	0.12	0.0	0.2	0.3			1.01	0.86	92.5
	3	22.0	5.7	240	7.5	109.5	0.02	0.0	0.2	0.2	0.20	0.20	0.24	1.38	97.5
27 Oct.	1	17.5	8.5	175	7.4	71.0		0.0	0.2	0.1					
	2	15.0	7.7	240	7.3	73.0		0.0	0.2	0.1					
	3	14.0	7.9	240	7.3	73.0		0.0	0.2	0.1					
1980															
5/7 May	A**	19.0	9.1	200	7.5	74.0	0.00	0.0	0.6	0.1	0.33	0.25	31.00	1.50	93.0
	1	16.0	9.5	210	7.5	65.0	0.03	0.0	0.3	0.1	0.00	0.28	20.80	1.75	103.0
	3	19.0	9.7	250	7.4	83.0	0.00	0.0	0.6	0.1	0.08	0.30	25.00	0.80	123.0
12 June	A	19.0	7.3	210	7.4	85.0	0.00	0.0	0.0	0.0					
	1	21.0	7.5	220	8.2	77.0	0.03	0.0	0.0	0.0	0.20	0.05	1.80	3.70	143.0
	3	22.0	7.5	255	7.1	93.0	0.00	0.0	0.0	0.0	0.22	0.30	2.80	6.70	165.0
4 Aug.	A	23.0	6.0	220	8.1	97.0	0.32	0.0	0.0	0.1	0.15	0.00	14.50	0.90	115.0
	1	20.0	6.8	235	8.1	88.4	0.40	0.0	0.6	0.2	0.05	0.10	2.80	1.50	130.0
	3	24.0	6.0	220	8.2	94.0	0.13	0.0	0.7	0.2	0.28	0.12	6.60	0.30	126.0
29/31 Oct.	A	12.0	9.0	210	7.3	100.0	0.10	0.0	0.1	0.0	0.05	0.05	24.80	2.50	90.0
	1	15.0	9.0	220	8.0	89.0	1.38	0.0	0.1	0.2	0.03	0.05	18.00	5.80	80.0
	3	11.0	9.1	240	7.6	95.0	0.26	0.0	0.1	0.1	0.15	0.25	12.50	7.80	128.0

*None of the samples collected contained odor of hydrogen sulfide.
**Station located in reservoir headwaters; see Appendix A, Figure A3.

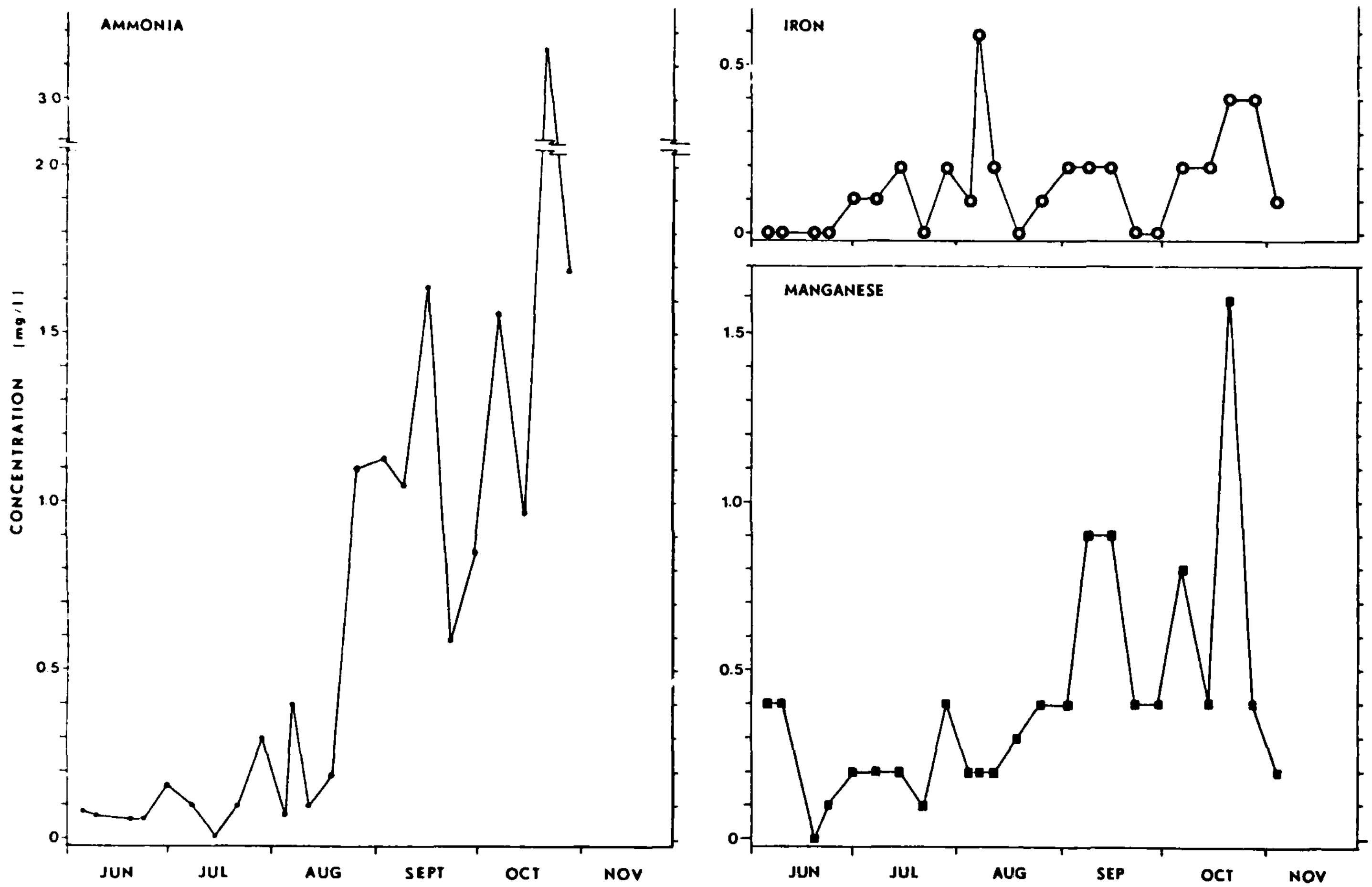

Figure 1. Concentration of ammonia, iron, and manganese at station 1 in the tailwater below Barren River Lake. Samples taken weekly June through October 1980

October. Dissolved oxygen concentrations were always 6.0 mg/ℓ or higher. Conductivity ranged between 200 and 220 μmhos/cm, which was usually lower than values found in the tailwater. The pH ranged 7.3 to 8.1, which was similar to values found in the tailwater. Alkalinity ranged from 74 mg/ℓ in May to 100 mg/ℓ in October. These values were higher than those found at tailwater station 1 but similar to those at tailwater station 3. Ammonia was found only in August and September samples; the concentration was highest in August. Sulfides were never detected at station A. Iron concentrations were high in May, but were low or nil in other months. Little or no manganese occurred in headwater samples. CPM levels (organic and inorganic combined) were high only in the spring; little occurred in summer and fall. FPIM levels were highest in the spring and were always higher in the headwater than in the tailwater. FPOM levels were highest in the fall but were always lower than those at tailwater station 1. TDS values ranged from 90 to 115 mg/ℓ, and were usually lower than in the tailwater.

Green

40. Reservoir. Thermal stratification was disrupted in 1979 as a result of large flood releases. A thermocline had formed at about 5 m by June but was transformed into a thermal gradient by August (Appendix F, Figure F5). In 1980, the reservoir was thermally stratified by mid-May at a depth of 6 m and remained stratified through mid-October. A clinograde oxygen profile was maintained from June throughout the summer of both years. The hypolimnion became depleted of oxygen earlier in 1979 than in 1980. Minimum dissolved oxygen levels in late June were less than 2 mg/ℓ in 1979, but were between 4 and 6 mg/ℓ in 1980.

41. Tailwater. Substantially higher mean daily flows occurred in the tailwater in 1979 than in 1980 (Appendix G, Figure G4). In 1979, minimum established flows (2.4 m^3/sec) occurred only for short periods in summer and were interrupted by large flood releases. Minimum flows were maintained in 1980 from early June through September. Maximum daily water temperatures during the summer of 1979 exceeded

21°C during minimum flows but were below 21°C during flood releases; maximum temperature was 25°C. In 1980, temperatures exceeded 21°C during June and July and reached a maximum of 24.5°C. Change in the depth of withdrawal kept temperatures below 21°C during sustained minimum releases in August and September.

42. Summer water temperatures at stations 2 and 3 were generally higher than at station 1 (Table 7). Seasonal dissolved oxygen values did not vary appreciably among stations and were generally greater than 6.0 mg/ℓ. Conductivity in the tailwater primarily ranged between 100 and 155 μmhos/cm in both 1979 and 1980. A high value of 295 μmhos/cm occurred at station 1 in June 1979. The pH at all stations was 6.9 or greater throughout both years. Tailwater alkalinities were generally lowest at station 1 and increased downstream. Ammonia concentrations were higher in August 1980 than in August 1979, but values were comparable during other seasons. Ammonia levels at station 1 were consistently higher than at other stations. Sulfides were not detected at any station when minimum flows were being released. Seasonal samples for iron and manganese indicated no substantial differences among stations or between years. There was no observable pattern in the distribution of particulate matter among the four stations. However, FPOM concentrations appeared to be slightly higher in 1979 than in 1980. TDS levels were also higher in August and October 1980 than in comparable periods in 1979.

43. Weekly (June to November) ammonia, iron, and manganese samples were taken in Green tailwater during 1980 (Figure 2). Ammonia was above 0.5 mg/ℓ on five occasions from mid-August through October and reached a maximum of 1.38 mg/ℓ. Iron reached or exceeded 0.3 mg/ℓ on one occasion in both September and October. Manganese concentrations were consistently above 0.05 mg/ℓ from August to November.

44. Headwater. Seasonal water samples were collected from Green reservoir headwater (station A) only in 1980 (Table 7). Water temperatures were higher than in tailwater stations, and dissolved oxygen concentrations were usually lower. Conductivity was also higher in the headwater. The pH was similar in the headwater and tailwater.

Table 7

Water Quality Variables Measured in the Tailwater below Green River Lake, 1979 and 1980

Date	Station	Temp. °C	DO mg/ℓ	Conductivity µmhos/cm	pH	Alkalinity mg/ℓ $CaCO_3$	Ammonia mg/ℓ	Sulfide mg/ℓ	Fe mg/ℓ	Mn mg/ℓ	CPIM mg/ℓ	CPOM mg/ℓ	FPIM mg/ℓ	FPOM mg/ℓ	TDS mg/ℓ
1979															
14 May	1	12.8	10.6	100	6.9	34.1	0.00	0.0*	0.2	0.0	0.20	0.45	1.50	11.50	66.0
	2	16.1	11.6	107	7.1	38.9	0.00	0.0	0.2	0.0	0.00	0.46	2.50	6.50	52.0
	3	18.3	12.2	113	7.4	43.1	0.00	0.0	0.2	0.0	0.11	0.31	2.50	6.00	62.0
20 June	1	20.6	8.4	295	7.0	37.8	0.00	0.0	0.1	0.0	0.25	0.03			57.5
	2	22.8	7.5	110	6.9	39.9	0.00	0.0	0.1	0.0	0.08	0.10	4.00	2.50	50.0
	3	23.3	7.3	110	7.0	44.1	0.00	0.0	0.1	0.0	0.60	0.05			60.0
9 Aug.	1	25.0	7.8	150	7.4	50.3	0.00	0.0	0.1	0.0	0.10	0.20	3.50	7.00	72.5
	2	26.0	6.1	150	7.2	54.1	0.00	0.0	0.2	0.0	0.10	0.20	3.00	8.80	62.5
	3	26.0	6.7	155	7.3	60.4	0.00	0.0	0.3	0.1	0.25	0.30	3.00	12.50	65.0
31 Oct.	1	16.0	9.1	115	7.2	44.0	0.20	0.0	0.2	0.1	0.35	0.53	2.30	10.00	58.5
	2	16.0	8.4	132	7.2	49.0	0.18	0.0	0.2	0.1	0.28	0.48	2.20	15.40	61.5
	3	16.0	8.4	146	7.3	53.0	0.17	0.0	0.2	0.1	0.22	0.71	2.40	20.00	73.8
1980															
28 April	A**	14.0	10.4	170	7.5	59.0	0.00	0.0	0.0	0.0	0.15	0.18	2.30	1.50	45.0
	1	12.0	9.9	130	7.4	39.0	0.03	0.0	0.9	0.0	0.00	0.10	3.20	3.30	90.0
	3	10.5	9.5	140	7.4	51.0	0.00	0.0	0.0	0.0	0.10	0.15	2.80	3.20	95.0
14 Aug.	A	27.0	5.9	210	8.1	85.0	0.21	0.0	0.3	0.2	0.30	0.15	9.50	2.30	120.0
	1	17.0	8.1	140	7.7	47.0	0.40	0.0	0.0	0.2	0.08	0.10	2.50	1.70	90.0
	3	24.0	6.4	145	8.2	50.0	0.22	0.0	0.1	0.2	0.03	0.05	6.10	1.10	105.0
22/23 Oct.	A	16.0	7.9	180	7.3	70.0	0.15	0.0	0.4	0.2	0.10	0.15	1.80	4.50	86.0
	1	17.5	9.5	130	7.7	50.0	0.22	0.0	0.4	0.2	0.08	0.10	1.00	0.50	103.0
	3	14.5	9.5	130	7.7	50.0	0.13	0.0	0.3	0.2	0.00	0.05	0.30	2.50	100.0

*None of the samples collected contained odor of hydrogen sulfide.
**Station located in reservoir headwaters; see Appendix A, Figure A4.

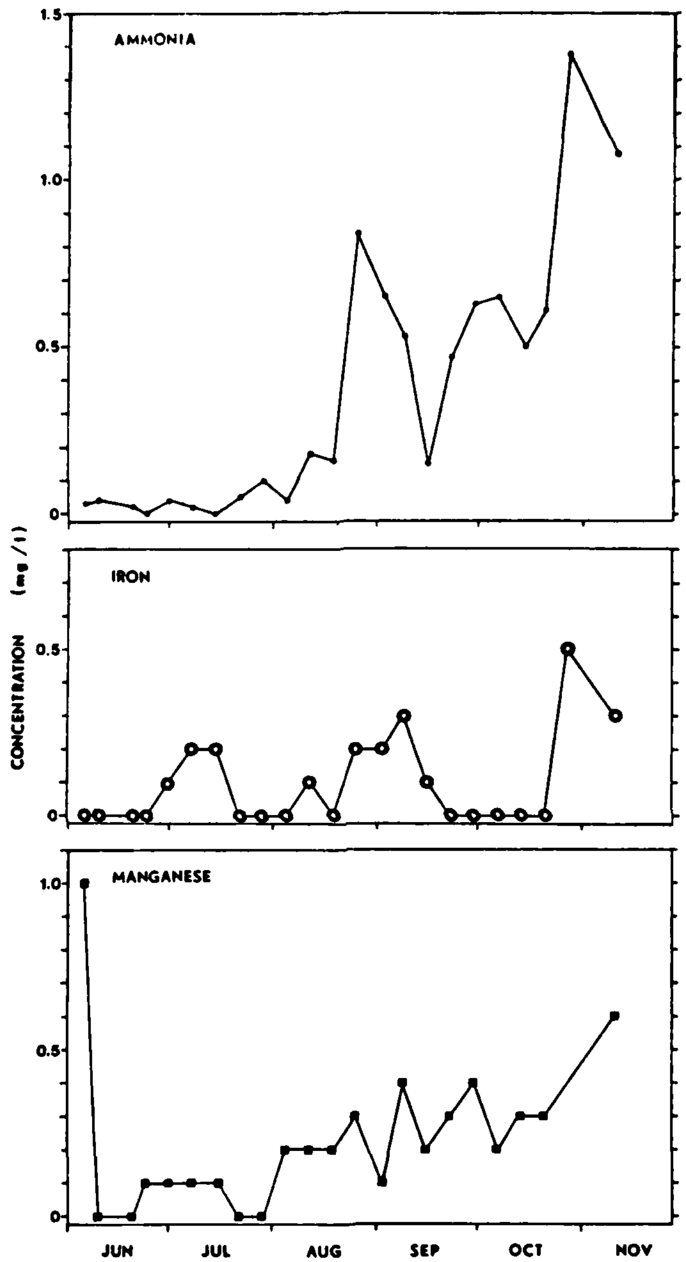

Figure 2. Concentration of ammonia, iron, and manganese at station 1 in the tailwater below Green River Lake. Samples taken weekly June to November 1980

Total alkalinities, which ranged from 59 to 85 mg/ℓ, were consistently higher than those in the tailwater. Ammonia concentrations were similar to those at tailwater station 3; values were highest at tailwater station 1. Sulfides were never detected at station A. Seasonal samples of iron and manganese indicated little difference between headwater and tailwater values. CPM levels (organic and inorganic combined) were always higher in the headwater than in the tailwater. Except for the April sample, FPIM and FPOM values were higher in the headwater than in the tailwater. Headwater TDS values were usually lower than those in the tailwater.

Beaver

45. Reservoir. Thermal stratification occurred in the summer of both 1979 and 1980 and the thermocline was maintained between a depth of 6 and 9 m (Appendix F, Figures F6 and F7). Oxygen levels remained high and were relatively uniform from the surface to bottom in the summer of both years. Slight decreases in dissolved oxygen were recorded in the metalimnion in 1979 and slight increases in 1980. A decreasing oxygen gradient was observed in the fall of 1979; levels ranged from 8.8 mg/ℓ at the surface to 2.2 mg/ℓ at the bottom. A similar gradient was observed in the 1980 fall profile, but the dissolved oxygen in the bottom 6 m was below 1 mg/ℓ.

46. Tailwater. Discharge fluctuations due to summer peaking operations were similar in both 1979 and 1980 (Appendix G, Figure G5). Maximum daily discharges were generally between 50 and 250 m^3/sec. Minimum flows (0.8 m^3/sec) were sustained for periods ranging from 6 to 31 days in April 1980 and in October, November, and December of both years.

47. Seasonal tailwater temperatures indicated few differences among stations (Table 8); water temperatures were near or below 13°C on all sampling dates. Dissolved oxygen was consistently above 6.0 mg/ℓ. Conductivity was similar between years and generally ranged from 120 to 200 μmhos/cm. Conductivity was highest in October 1979, when it reached 320 μmhos/cm at station 4. The pH did not vary appreciably among stations and was generally above 7.0. Lowest pH's

Table 8

Water Quality Variables Measured in the Tailwater below Beaver Lake, 1979 and 1980

Date	Station	Temp. °C	DO mg/ℓ	Conductivity umhos/cm	pH	Alkalinity mg/ℓ $CaCO_3$	Ammonia mg/ℓ	Sulfide mg/ℓ	Fe mg/ℓ	Mn mg/ℓ	CPIM mg/ℓ	CPOM mg/ℓ	FPIM mg/ℓ	FPOM mg/ℓ	TDS mg/ℓ
1979															
14 June	2	7.2	10.0	196	7.6	75.0	<0.1	0.00*	0.1	0.0	0.02	0.16	1.00	0.75	76.0
	3	7.8	9.2	129	7.5	81.3	0.1	0.00	0.1	0.0	0.11	0.11	1.00	1.00	78.0
28 June	2	10.6	9.9	196	7.6	77.5	<0.1	0.00	0.1	0.0					
	3	11.0	9.5	178	7.6	85.0	0.1	0.00	0.1	0.0					
10 July	2	11.5	11.8	140	7.4	87.5	<0.1	0.00	0.0	0.0	0.05	0.06	0.10	0.65	74.5
	3	11.0	12.2	142	7.3	82.5	0.1	0.00	0.1	0.0	0.04	0.02	0.60	0.80	71.3
4 Oct.	2	13.1	12.2	230	7.5	85.0	<0.1	0.00	0.1	0.1	0.28	0.25	0.17	0.00	83.1
	3	11.7	11.6	220	7.6	77.5	0.1	0.00	0.1	0.1					77.7
	4	12.5	10.4	320	7.2	85.0	<0.1	0.00	0.1	0.1	0.10	0.22	0.00	0.12	110.9
1980															
6 Feb.	2	6.5	10.5	146	7.2	55.6	<0.1	0.00	0.1	0.1	0.00	0.00	0.00	0.00	82.8
4 April	2	11.0	11.0	135	7.9			0.00	0.0	0.0					
	3	11.5	11.1	220	7.4		0.1	0.00	0.1	0.0					
	4	11.5	11.1	150	7.5			0.00	0.2	0.0					
29 April	2	9.0	10.1	168	7.9	93.7	<0.1	0.00	0.1	0.0	0.44	0.20	0.15	1.90	81.9
	3	7.0	11.6	174	7.5	77.0	<0.1	0.00	0.1	0.0	0.25	0.13	2.70	0.80	82.5
	4	7.5	9.8	164	8.3	88.3	<0.2	0.00	0.0	0.0	0.40	0.25	2.95	2.00	83.0
28 May	2	10.0	11.4	130	7.8	83.3	<0.1	0.00	0.0	0.0	0.07	0.08	1.00	0.10	82.2
	3	11.0	11.2	140	7.8	90.0	<0.1	0.00	0.1	0.0	0.24	0.04	0.60	0.10	90.0
	4	12.0	10.8	175	7.8	106.7	<0.1	0.00	0.0	0.0	0.04	0.03	0.45	0.20	91.4
20 June	2	8.9	12.1	125	6.8	76.7	<0.1	0.00	0.0	0.0	0.06	0.01	1.50	0.30	86.0
	3	9.7	11.6	130	6.8	56.7	<0.1	0.00	0.0	0.0	0.04	0.01	0.50	0.95	84.3
	4	12.2	11.4	135	6.8	53.3	<0.1	0.00	0.0	0.0	0.06	0.02	0.70	0.85	83.6
25 Sept.	2	8.6	6.9	128	6.5	83.3	<0.7	0.00	0.0	0.0	0.03	0.10	1.10	0.65	85.8
	3	9.4	8.1	120	6.3	85.0	<0.7	0.00	0.0	0.0	0.17	0.09	1.00	0.65	82.5
	4	10.0	8.8	125	6.4	83.3	<0.1	0.00	0.0	0.0	0.04	0.09	0.80	0.85	83.5
29 Oct.	2	11.1	8.9	135	6.7										
	3	8.9	11.2	145	6.6										
	4	8.9	11.2	143	6.7										
16 Dec.	2	8.3	7.0	141	6.8	57.5	<0.1	0.00	0.0	0.0	0.04	0.03	1.65	0.85	81.7
	3	8.3	9.9	145	7.1	58.5	<0.1	0.00	0.2	0.1	0.04	0.23	1.00	1.10	83.6
	4	7.8	10.5	136	7.8	60.5	<0.1	0.00	0.1	0.1	0.04	0.20	1.15	1.40	85.8

*None of the samples collected contained odor of hydrogen sulfide.

were recorded at all three stations in September 1980. Alkalinity generally ranged between 50 and 100 mg/ℓ and did not vary extensively by station or season. Ammonia was usually less than 0.1 mg/ℓ but reached 0.7 mg/ℓ at stations 2 and 3 in September 1980. The odor of hydrogen sulfide was not detected in any of the samples. Iron and manganese concentrations were less than 0.2 mg/ℓ in both years. Particulate matter was consistently low. CPIM and CPOM were less than 0.44 mg/ℓ and FPIM and FPOM less than 2.95 mg/ℓ. TDS generally remained between 70 and 90 mg/ℓ.

Hartwell

48. Reservoir. The reservoir began to stratify thermally in April during both 1979 and 1980 and remained stratified through October of both years (Appendix F, Figures F8 and F9). A hypolimnion, reduced in volume, was still present in the bottom 3 m in November 1979. A clinograde oxygen profile had formed by late July of both years. By mid-August 1979, the hypolimnion had become anoxic in the bottom 5 m, and by October the entire hypolimnion was anoxic in both years. Anoxic conditions were still evident in the bottom 3 m of the reservoir in November 1979; however, water in the upper 48 m was reaerated.

49. Tailwater. Daily flow fluctuations during peaking operations were greater and more uniform in 1979 than in 1980 (Appendix G, Figure G6). Maximum peaking flows were generally between 500 and 800 m^3/sec throughout 1979, and ranged between 100 and 800 m^3/sec in 1980. Maximum peaking flows were consistently low, generally less than 100 m^3/sec, from mid-September through early November 1980. Weekend flows did not usually exceed 20 m^3/sec. Daily maximum water temperatures recorded 7.2 km below the dam (station 2) in 1979 fluctuated over a wide range in spring, but were generally maintained between 20 and 24°C during summer (Appendix G, Figure G7). Maximum spring and summer water temperatures were probably lower immediately below the dam, as indicated in Table 9.

50. Water temperatures at station 1 were lower than at stations 2 and 3 in spring and summer and higher in autumn and winter (Table 9). Low dissolved oxygen was observed at station 1 in July (4.1 mg/ℓ) and

Table 9

Water Quality Variables Measured in the Tailwater below Hartwell Lake, 1979 and 1980

Date	Station	Temp. °C	DO mg/ℓ	Conductivity µmhos/cm	pH	Alkalinity mg/ℓ $CaCO_3$	Ammonia mg/ℓ	Sulfide* mg/ℓ	Fe mg/ℓ	Mn mg/ℓ	CPIM mg/ℓ	CPOM mg/ℓ	FPIM mg/ℓ	FPOM mg/ℓ	TDS mg/ℓ
1979															
10 April	1	8.9	10.5	34	6.8	12.5	0.00	0.00	0.0	0.0	0.00	0.05	0.00	1.30	
	2	9.6	10.5	34	6.8	10.0	0.10	0.00	0.0	0.0	0.06	0.10	0.00	0.80	
	3	9.9	10.9	34	6.8	12.5	0.00	0.00	0.0	0.0	0.14	0.12	0.30	1.80	24.0
10 May	1	10.4	8.9	34	6.3	12.0	0.00	0.00	0.0	0.0	0.12	0.11	1.85	1.50	21.5
	2	14.9	8.0	59	6.2	14.0	0.00	0.00	1.2	0.4	1.37	1.42	21.15	5.10	47.5
	3	11.2	9.2	36	6.2	10.5	0.00	0.00	0.1	0.0	0.06	0.06	1.25	0.80	26.0
30 July	1	17.1	4.1	35	6.0	9.5	0.00	0.76	0.1	0.1					
	2	22.6	8.5	45	6.6	11.0	0.00	0.16	0.4	0.1					
	3	24.2	8.3	47	6.7	12.5	0.00	0.76	0.5	0.1					
16 Aug.	1	17.2	6.3	35	6.0	0.0	0.00	0.76	0.2	0.1	2.96	0.46	1.25	1.75	
	2	17.6	8.3	38	6.3	4.0	0.00	0.76	0.2	0.1	0.22	0.20	1.10	1.60	
	3	17.8	8.2	35	6.4	9.2	0.00	0.76	0.1	0.1	2.76	0.24	1.25	1.45	125.0
12 Sept.	1	19.4	2.2	39	5.8	11.0	0.00	0.76	0.3	0.3	0.24	0.11	0.00	1.90	253.0
	2	19.9	8.0	38	6.3	11.5	0.00	0.76	0.2	0.2	1.02	0.28	0.00	1.25	179.0
	3	19.8	8.0	38	6.3	13.5	0.00	0.16	0.2	0.2	0.34	11.60	0.00	1.55	121.0
24 Oct.	1	20.8	7.6	41	6.2	12.0	0.00	1.36	0.6	0.3	0.03	0.08	0.80	0.85	25.0
	2	20.3	7.1	41	6.2	13.0	0.00	1.56	0.7	0.3	0.20	0.16	0.70	0.65	94.5
	3	18.1	8.0	41	6.4	11.0	0.00	1.36	0.5	0.2	0.45	0.16	1.40	0.85	140.5
2 Nov.	1	17.8	7.7	38	6.3	12.5	0.00		0.2	0.1			0.30	0.30	19.5
	2	17.7	7.8	38	6.3	11.0	0.00		0.2	0.1	0.63	0.13	0.30	0.15	
	3	17.9	8.2	38	6.4	10.5	0.00		0.3	0.1	0.36	1.28	0.10	0.40	
1980															
27 Feb.	1	8.9	12.5	38	6.8	16.5	0.00	1.36	0.0	0.0	0.22	0.09	0.65	0.65	48.5
	2	10.2	13.2	39	6.9	18.0	0.00	0.96	0.1	0.0	0.06	0.09	0.00	0.10	25.5
	3	7.6	13.3	45	7.2	17.0	0.00	0.96	0.1	0.0	0.16	0.70	0.00	0.20	
30 May	1	12.9	8.8	37	6.3	15.0	0.00	0.00	0.0	0.0	0.12	0.36	0.75	1.40	
	2	13.1	9.0	39	5.9	13.5	0.00	1.16	0.0	0.0	1.41	0.20	0.90	1.00	76.5
	3	13.6	9.4	38	6.2	13.0	0.00	0.00	0.0	0.0	0.81	0.33	2.35	3.30	33.5
30 July	1	20.0	10.6	42	6.5	16.0	0.00		0.1	0.0	0.70	0.31	1.35	0.75	30.0
	2	23.3	7.5	46	6.7	12.0	0.00		0.2	0.0	0.24	0.04	1.75	0.75	50.5
	3	18.7	9.0	41	7.3	12.0	0.00		0.2	0.1	1.40	0.14	2.30	0.75	35.0
27 Oct.	1	20.4	8.2	41	6.1	26.0	0.00	0.00	0.5	0.3	0.06	0.01	0.10	0.55	102.0
	2	18.2	7.7	42	6.2	16.5	0.00	0.00	0.4	0.3	0.42	1.78	0.05	0.10	14.0
	3	14.5	9.8	63	6.9	22.0	0.00	0.00	0.6	0.1	0.47	0.14	0.00	0.50	29.0

* Sulfide odor not consistently detected when analyses indicated presence of sulfide.

September (2.2 mg/ℓ) in 1979. Dissolved oxygen at stations 2 and 3 was seldom less than 8.0 mg/ℓ. Conductivity did not vary by season or station and seldom exceeded 50 μmhos/cm. The pH ranged from 5.8 to 7.3 and appeared to have no recognizable pattern either seasonally or by station. Alkalinities were slightly higher in 1980 than in 1979 but were never greater than 26.0 mg/ℓ. Ammonia was detected only at station 2 in April 1979. Sulfide concentrations were greater than 0.76 mg/ℓ in most samples taken between July 1979 and May 1980 but at other times none was detected. However, the results of the sulfide analyses may be incorrect since sulfide odor was not consistently detected. Iron was variable; it was high at station 2 in May 1979, stations 2 and 3 in July 1979, and at all three stations in October 1979 and 1980. Manganese was also variable; the highest value (0.4 mg/ℓ) was recorded at station 2 in May 1979, and concentrations of 0.3 mg/ℓ were observed in September 1979 and October 1979 and 1980. Particulate matter, both coarse and fine, was generally less than 2.0 mg/ℓ at all stations. Highest CPOM (11.60 mg/ℓ) occurred at station 3 in September 1970; highest FPIM (21.15 mg/ℓ) and FPOM (5.10 mg/ℓ) occurred at station 2 in May 1979. TDS did not usually exceed 100 mg/ℓ; however, a value greater than 250 mg/ℓ was recorded at station 1 in September 1979.

<u>Greeson</u>

51. <u>Reservoir.</u> Thermal stratification began in early May 1979, and continued through mid-October (Appendix F, Figure F10). Metalimnetic oxygen lower than 1 mg/ℓ was observed from mid-July through mid-October. Hypolimnetic oxygen generally remained high during this period, although anoxic conditions were observed within the bottom metre in the October profile.

52. <u>Tailwater.</u> Daily maximum discharges were generally between 50 and 75 m^3/sec during peaking operations in 1979 (Appendix G, Figure G8). Hydropower discharges in April and May were sustained for periods of 2 to 8 days. Sustained minimum flows (0.3 m^3/sec) were recorded for a period of 11 days in September. On weekends, power was generally not produced, and tailwater flows were limited to dam leakage (0.3 m^3/sec).

53. Water temperatures recorded at station 1 in July and September were 5 to 11°C lower than at station 3 (Table 10). Temperatures did not differ appreciably among stations in May, June, or October. Dissolved oxygen at all stations was always above 5.0 mg/ℓ. Conductivity ranged from 28 to 78 μmhos/cm and was highest at station 3. The pH did not vary appreciably among stations and ranged between 5.0 and 6.0. Alkalinities were low at all stations; the highest value (12.6 mg/ℓ) occurred at station 3 in October. Ammonia concentrations were always less than 0.1 mg/ℓ, and sulfides were never detected. Iron was never less than 0.2 mg/ℓ, and highest concentrations occurred at station 1 in September and October. Manganese generally equaled or exceeded 0.1 mg/ℓ; the highest levels were at station 1 in September and October. Particulate matter did not vary appreciably by station or season. CPIM and CPOM never exceeded 0.4 mg/ℓ, and FPIM and FPOM levels were usually less than 3.2 mg/ℓ. TDS was generally between 30 and 70 mg/ℓ and never above 100 mg/ℓ.

Macroinvertebrates

Pine Creek

54. Drift. Macroinvertebrate densities and biomass in the drift were higher at station 1 than at station 3; however, numbers of taxa and diversity were greater at station 3 (Table 11). Chaoboridae, Chironomidae, and Oligochaeta were generally the most numerous drift organisms at station 1. The differences in densities and biomass between stations were caused primarily by reduced numbers of Chaoboridae and Chironomidae at the downstream station. Other taxa that were moderately more abundant at station 1 included Simuliidae, Culicidae, and Trichoptera. Organisms more common to natural streams, such as Ephemeroptera, Plecoptera, and Hydracarina, were the only groups whose abundance increased downstream.

55. Hess. Highest densities and biomass of macroinvertebrates were found at station 1, immediately below the dam (Table 12). At the two downstream stations, densities and biomass were reduced by as much

Table 10

Water Quality Variables Measured in the Tailwater below Lake Greeson, 1979

Date	Station	Temp. °C	DO mg/ℓ	Conductivity µmhos/cm	pH	Alkalinity mg/ℓ $CaCO_3$	Ammonia mg/ℓ	Sulfide mg/ℓ	Fe mg/ℓ	Mn mg/ℓ	CPIM mg/ℓ	CPOM mg/ℓ	FPIM mg/ℓ	FPOM mg/ℓ	TDS mg/ℓ
1979															
5 May	1	14.0	9.6	28	5.9	4.0	0.00	0.0*	0.2	0.1	0.00	0.02	1.34	1.30	55.7
	2	13.5	8.8	28			0.00	0.0	0.2	0.0	0.40	0.31	2.72	1.95	38.6
	3	16.0	8.6	78	5.2		0.00	0.0	0.4	0.1			0.44	1.75	99.3
21 June	1	21.0	9.0	34			0.00	0.0	0.3	0.1	0.18	0.09	1.35	1.40	80.6
	2	17.6	7.4	30	6.0	4.5	0.00	0.0	0.2	0.1	0.28	0.29	2.30	1.30	50.0
	3	19.2	6.4	61	5.6	8.0	0.00	0.0	0.3	0.1	0.08	0.18	7.40	1.70	97.7
18 July	1	16.5	6.7	30	5.5	4.0	0.00	0.0	0.2	0.1	0.06		2.40		8.8
	2	18.0	6.9	32	5.2	5.0	0.00	0.0	0.2	0.2	0.03	0.12	1.79		30.2
	3	21.5	7.5	38	5.7	3.5	0.06	0.0	0.2	0.2			3.20		37.4
5 Sept.	1	18.0	5.6	36	5.2	3.0	0.00	0.0	0.8	0.4	0.00	0.05	0.64	1.06	35.9
	2	26.5	6.5	34	5.5	4.5	0.00	0.0	0.3	0.1	0.00	0.01	2.55	1.06	29.9
	3	27.5	7.5	48	5.7	10.0	0.00	0.0	0.3	0.1	0.01	0.35	1.54	1.12	80.3
16 Oct.	1	20.5	8.4	33	5.4	8.7	0.00	0.0	0.6	0.3	0.01	0.02	1.01	0.37	69.1
	2	18.0	6.8	32	5.3	7.8	0.02	0.0	0.5	0.2	0.09	0.00	1.38	0.75	57.1
	3	18.0	7.3	48	5.2	12.6	0.00	0.0	0.4	0.1	0.22	0.00	2.34	0.21	65.9

*None of the samples collected contained odor of hydrogen sulfide.

Table 11

Taxonomic Composition, Mean Numbers, Mean Biomass, Total Taxa, and Diversity of Macroinvertebrates Collected with a Drift Sampler at Two Stations in the Tailwater below Pine Creek Lake, 1979 and 1980

Taxon	Stations Mean Numbers, No./1000 m^3 1	3
Diptera		
Chironomidae	4,130	432
Chaoboridae	15,387	553
Simuliidae	20	4
Culicidae	65	36
Ceratopogonidae	4	2
Trichoptera	56	25
Ephemeroptera	10	180
Plecoptera	1	10
Coleoptera	13	2
Lepidoptera	9	0
Hydracarina	2	24
Oligochaeta	179	15
Amphipoda	8	2
Isopoda	8	0
Other*	12	4
Total	19,904	1,289
Mean biomass, mg/1000 m^3	5,736	392
Total taxa	51	63
Shannon-Weaver index	1.26	3.14
Number of samples	10	11

*Includes Empididae, Tipulidae, Tabanidae, Odonata, Hemiptera, Megaloptera, Orthoptera, Nematoda, and Hirudinea.

Table 12

Taxonomic Composition, Mean Numbers, Mean Biomass, Total Taxa, and Diversity of Macroinvertebrates Collected with a Hess Sampler at Three Stations in the Tailwater below Pine Creek Lake, 1979 and 1980

Taxon	Stations: Mean Numbers, No./m^2		
	1	2*	3
Diptera			
Chironomidae	25,460	8,221	10,152
Simuliidae	106	2	4
Empididae	1,039	2	6
Chaoboridae	6	24	0
Trichoptera	540	588	1,096
Ephemeroptera	90	126	1,585
Plecoptera	0	0	25
Coleoptera	18	0	27
Odonata	86	43	156
Hydracarina	670	258	204
Oligochaeta	3,929	612	854
Hirudinea	97	2	22
Nematoda	208	74	44
Amphipoda	58	74	94
Isopoda	2,378	35	280
Gastropoda	20	0	6
Ostracoda	234	1,420	242
Other**	24	2	49
Total	34,963	11,483	14,846
Mean biomass, mg/m^2	3,784	1,045	2,502
Total taxa	27	32	38
Shannon-Weaver index	1.76	1.66	1.99
Number of samples	10	6	8

*1979 only.

**Includes Ceratopogonidae, Tabanidae, Megaloptera, Neuroptera, Ostracoda, Decapoda, and Gastropoda.

as 60 percent. Numbers of taxa were fewest at station 1 but increased progressively downstream. Diversities were relatively low at all three stations, the highest value being at station 3. Chironomidae, Oligochaeta, Isopoda, and Empididae were the major taxa collected at station 1. Abundance of all four of these taxa decreased downstream, but Chironomidae remained numerically dominant at all stations. Other taxa that were more common at station 1 than at downstream stations were Simuliidae, Hydracarina, Hirudinea, Nematoda, and Gastropoda. Again, typical riverine species such as Trichoptera, Ephemeroptera, Plecoptera, Coleoptera, Odonata, and Amphipoda increased in abundance downstream.

Gillham

56. Drift. Macroinvertebrate densities and biomass in Gillham tailwater drift were highest at station 1 and decreased downstream (Table 13). However, both total taxa and diversity were highest at station 3. The drift at station 1 was dominated by Chaoboridae, which made up 94 percent of the organisms; other common taxa were Chironomidae and Simuliidae. All taxa collected at station 1, except Chaoboridae, were more numerous downstream, where Ephemeroptera, Chironomidae, and Simuliidae were most abundant.

57. Hess. Densities, biomass, diversity, and number of taxa were greatest at station 3 in Gillham tailwater (Table 14). Densities were also relatively high at stations 1 and 2, and biomass was highest at station 1. Chironomidae and Oligochaeta were numerically dominant at station 1. Chironomidae, Oligochaeta, Trichoptera, and Hydracarina were numerically dominant at station 2, and Ephemeroptera, Chironomidae, Plecoptera, and Trichoptera at station 3. Most insects collected in the Gillham tailwater (except Chironomidae) increased in abundance from station 1 to station 3. Noninsects (except Hydracarina) were most abundant at stations 1 and 2.

Barren

58. Drift. Obvious trends in drift densities and biomass were not evident among sample sites in the Barren River (Table 15). However, numbers of taxa and diversity increased from station 1 to

Table 13

Taxonomic Composition, Mean Numbers, Mean Biomass, Total Taxa, and Diversity of Macroinvertebrates Collected with a Drift Sampler at Two Stations in the Tailwater below Gillham Lake, 1979 and 1980

Taxon	Stations Mean Numbers, No./1000 m^3 1	3
Diptera		
Chironomidae	135	188
Chaoboridae	3400	15
Simuliidae	54	135
Trichoptera	16	51
Ephemeroptera	4	270
Plecoptera	1	52
Coleoptera	0	52
Hydracarina	1	36
Oligochaeta	4	8
Other*	4	14
Total	3619	821
Mean biomass, mg/1000 m^3	1191	412
Total taxa	29	67
Shannon-Weaver index	0.99	4.72
Number of samples	9	9

*Includes Athericidae, Empididae, Ephydridae, Culicidae, Hemiptera, Pyralidae, Corydalidae, Nematoda, Ostracoda, and Decapoda.

Table 14

Taxonomic Composition, Mean Numbers, Mean Biomass, Total Taxa, and Diversity of Macroinvertebrates Collected with a Hess Sampler at Three Stations in the Tailwater below Gillham Lake, 1979 and 1980

Taxon	Stations: Mean Numbers, No./m^2 1	2*	3
Diptera			
Chironomidae	8,442	9,422	4,090
Simuliidae	8	4	368
Empididae	30	246	8
Chaoboridae	25	12	0
Trichoptera	275	1,477	1,941
Ephemeroptera	69	495	7,195
Plecoptera	37	12	3,926
Coleoptera	258	110	970
Megaloptera	40	4	33
Odonata	0	8	65
Hydracarina	2	1,449	452
Oligochaeta	6,412	1,412	306
Nematoda	14	213	40
Amphipoda	12	0	4
Isopoda	14	4	0
Ostracoda	34	25	0
Other**	13	16	44
Total	15,685	14,909	19,442
Mean biomass, mg/m^2	2,550	976	3,866
Total taxa	29	29	39
Shannon-Weaver index	1.40	1.91	3.26
Number of samples	8	4	9

*1979 only.
**Includes Culicidae, Tabanidae, Tipulidae, Lepidoptera, Neuroptera, and Decapoda.

Table 15

Taxonomic Composition, Mean Numbers, Mean Biomass, Total Taxa, and Diversity of Macroinvertebrates Collected with a Drift Sampler at Three Stations in the Tailwater below Barren River Lake and at One Station Located above the Reservoir, 1979 and 1980

Taxon	Stations: Mean Numbers, No./1000 m^3 1	2*	3	A**
Diptera				
Chironomidae	758	1155	342	262
Simuliidae	157	37	96	20
Chaoboridae	1598	7276	594	0
Trichoptera	18	95	124	142
Ephemeroptera	45	219	656	646
Plecoptera	tr†	4	47	147
Coleoptera	6	27	65	32
Oligochaeta	20	2	27	31
Hydracarina	2	715	8	6
Turbellaria	1	0	tr	0
Terrestrials	25	3	102	20
Other††	5	4	19	17
Total	2635	9537	2080	1323
Mean biomass, mg/1000 m^3	296	1358	334	187
Total taxa	25	27	42	42
Shannon-Weaver index	1.50	1.28	3.37	3.86
Number of samples	8	4	8	4

*1979 only.
**Located above reservoir; sampled only in 1980.
†tr = Less than 0.5.
††Includes Culicidae, Empididae, Tabanidae, Tipulidae, Megaloptera, Corixidae, Odonata, Lepidoptera, Amphipoda, Isopoda, and Decapoda.

station 3. The highest diversity occurred at the above-reservoir station A, although total taxa at stations 3 and A were similar. Most of the macroinvertebrates collected in the drift at stations 1 and 2 were larval Diptera, primarily Chaoboridae. The three major families of Diptera (Chaoboridae, Chironomidae, and Simuliidae) were common at stations 1 and 2, less numerous at station 3, and least numerous above the reservoir. The taxonomic composition of the macroinvertebrates at stations 3 and A was similar except for the absence of Chaoboridae at station A. Trichoptera, Ephemeroptera, and Plecoptera were progressively more abundant downstream from stations 1 to 3. Ephemeroptera and Plecoptera were most abundant above the reservoir; numbers of Trichoptera were similar at stations 3 and A.

59. Hess. Density and biomass estimates determined from Hess samples in the Barren tailwater were highest at station 1 and decreased downstream (Table 16). The greatest number of taxa and highest diversities were at station 3. Density, biomass, total taxa, and diversity were all higher above the reservoir than at any of the three tailwater stations. Chironomidae, Simuliidae, Oligochaeta, and Turbellaria were all common at tailwater station 1 but decreased in abundance downstream. Ephemeroptera, common at station 1, increased in abundance, along with most other taxa, downstream. Every major taxon collected at the Barren sampling stations, except Simuliidae and Turbellaria, was more abundant above the reservoir.

60. Hester-Dendy. This sampling device gave variable estimates of density and biomass at the four stations; both values were highest at station 2 (Table 17). Both the total numbers of taxa and diversity indices were similar at stations 1, 2, and A, and highest at station 3. Hester-Dendy samplers collected the fewest taxa and yielded the lowest diversity of any of the sampling methods used on the Barren River. Definite upstream-downstream trends in taxonomic abundance were not evident from the Hester-Dendy data. Simuliidae were most abundant, and Ephemeroptera and Trichoptera least abundant, at station 1. Chironomidae was the dominant invertebrate taxon at all four stations.

Table 16

Taxonomic Composition, Mean Numbers, Mean Biomass, Total Taxa, and Diversity of Macroinvertebrates Collected with a Hess Sampler at Three Stations in the Tailwater below Barren River Lake and at One Station Located above the Reservoir, 1979 and 1980

	Stations: Mean Numbers, No./m^2			
Taxon	1	2*	3	A**
Diptera				
Chironomidae	6,052	2,946	1,718	5,195
Simuliidae	980	129	434	12
Trichoptera	24	32	110	391
Ephemeroptera	520	860	1,402	3,211
Plecoptera	7	32	22	102
Coleoptera	34	86	70	220
Oligochaeta	1,358	376	335	6,710
Hydracarina	3	11	24	40
Turbellaria	186	108	112	30
Other†	32	40	20	231
Total	9,196	4,620	4,247	16,142
Mean biomass, mg/m^2	397	340	284	1,742
Total taxa	26	18	31	46
Shannon-Weaver index	1.65	1.47	2.63	2.83
Number of samples	24	12	24	12

*1979 only.
**Located above reservoir; sampled only in 1980.
†Includes Athericidae, Empididae, Chaoboridae, Ceratopogonidae, Tabanidae, Tipulidae, Megaloptera, Odonata, Lepidoptera, Gastropoda, Amphipoda, Isopoda, and Decapoda.

Table 17

Taxonomic Composition, Mean Numbers, Mean Biomass, Total Taxa, and Diversity of Macroinvertebrates Collected with Hester-Dendy Samplers at Three Stations in the Tailwater below Barren River Lake and at One Station Located above the Reservoir, 1979 and 1980

Taxon	Stations: Mean Numbers, No./m^2 1	2*	3	A**
Diptera				
Chironomidae	6,280	34,887	1,480	9,859
Simuliidae	34	14	12	5
Trichoptera	112	422	168	444
Ephemeroptera	26	908	252	300
Plecoptera	0	0	tr†	0
Coleoptera	0	49	2	0
Oligochaeta	570	1,683	219	89
Hydracarina	0	211	tr	0
Turbellaria	65	0	26	0
Other††	7	239	26	2
Total	7,094	38,413	2,185	10,699
Mean biomass, mg/m^2	484	1,280	345	398
Total taxa	14	15	22	17
Shannon-Weaver index	0.76	0.65	1.94	0.64
Number of samples	14	5	14	8

*1979 only.
**Located above reservoir; sampled only in 1980.
†tr = Less than 0.5.
††Includes Empididae, Ceratopogonidae, Tipulidae, Odonata, Lepidoptera, Neuroptera, Megaloptera, and Gastropoda.

61. Ordinate analysis and functional group. The condition of the macroinvertebrate communities in the Barren tailwater was determined by comparison of Hess samples collected at stations 1, 3, and A in 1980 (Figure 3). Most of the stations 1 and 3 samples were located in Quadrant III, where both total numbers and taxa were low, indicating a highly stressed community brought about by negative environmental conditions. A few samples from these locations fell within Quadrant I, indicating that the benthic community in the tailwater was affected occasionally by selective stresses which reduced numbers of taxa, but increased total numbers of tolerant organisms; no stations 1 or 3 samples were in Quadrants II or IV. Generally, samples from the two tailwater stations were interspersed, making them appear to be equally affected by environmental perturbations.

62. Invertebrate functional feeding types varied among the three Barren River stations sampled in 1980 (Figure 4). The above-reservoir station was assumed to be representative of a stream before impoundment. Collectors dominated the numerical composition, but the other groups (predators, shredders, and scrapers) were also well represented. Invertebrate communities at both tailwater stations were composed primarily of collectors. At station 1, members of the other functional groups were seldom collected; predators and shredders were more common farther downstream, but scrapers continued to be rare.

Green

63. Drift. Drifting organisms were more numerous, and biomass estimates were highest at station 3 (Table 18). Density and biomass at other stations, both in the tailwater and above the reservoir, were similar. More taxa were also collected at station 3, but diversity there was similar to that at stations 1 and 2. Diversity was higher above the reservoir than in the tailwater. Green tailwater drift was dominated by Chaoboridae at station 1, but Chironomidae, Trichoptera, and Simuliidae were also abundant. Downstream, numbers of Chaoboridae were reduced, and typical riverine species such as Trichoptera, Ephemeroptera, Hydracarina, and Coleoptera were more abundant. Above the reservoir, Ephemeroptera, Chironomidae, and Plecoptera were most

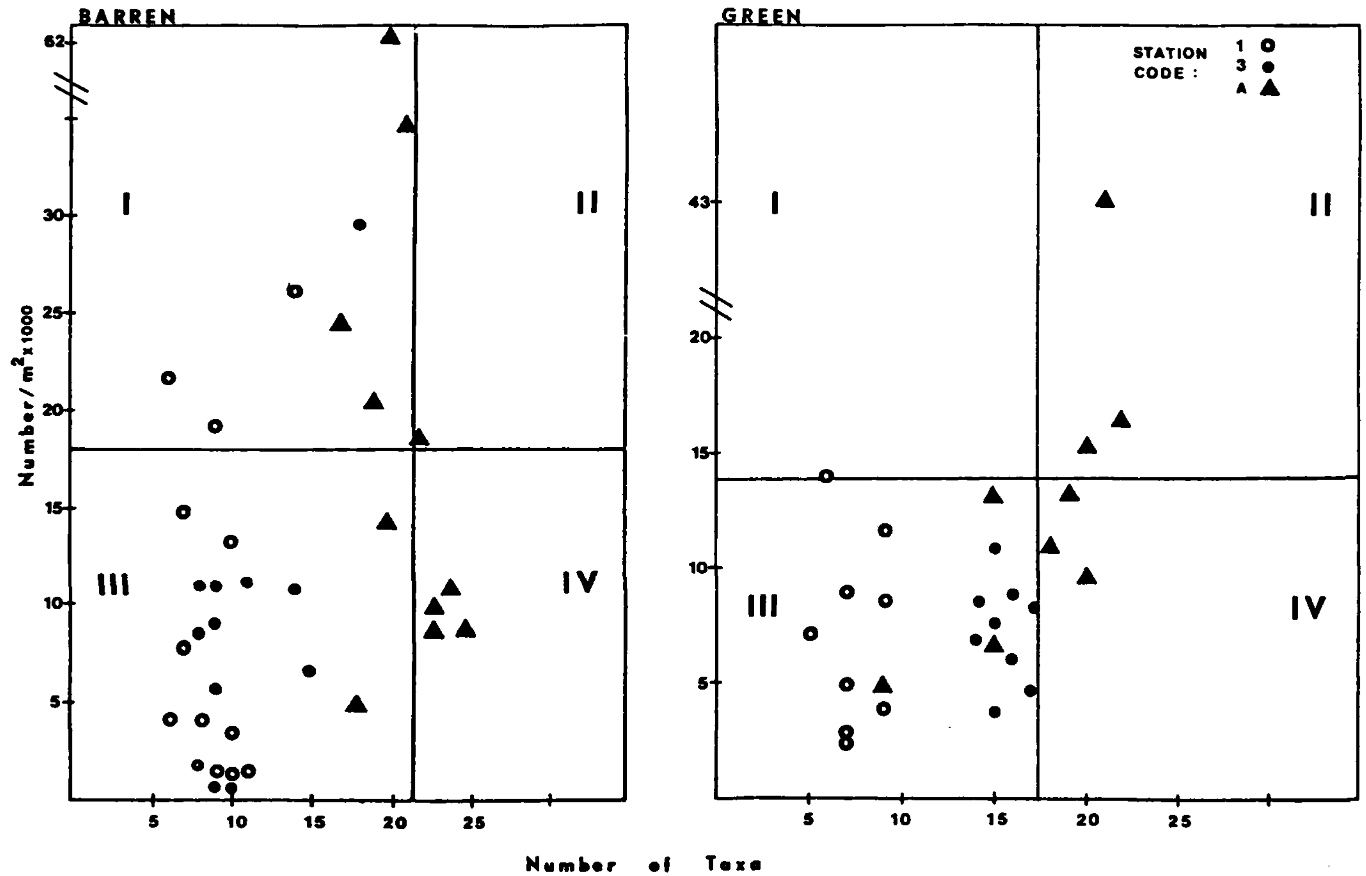

Figure 3. Ordination of the numbers of taxa and total numbers/m^2 of macroinvertebrates collected with the Hess sampler at stations 1, 3, and A in the Barren and Green Rivers, 1980

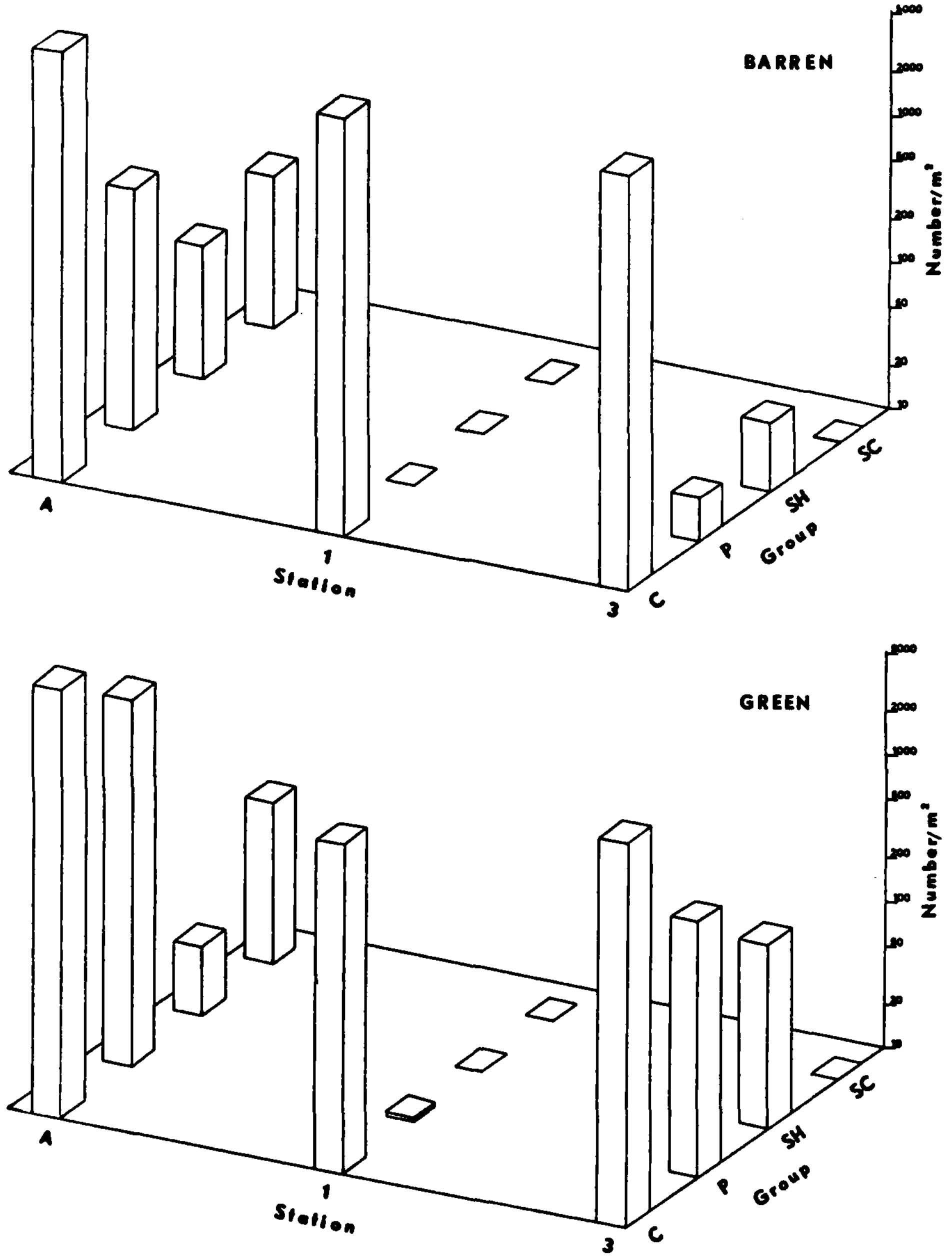

Figure 4. Distribution of macroinvertebrate functional feeding groups, including collectors (C), predators (P), shredders (SH), and scrapers (SC) at tailwater stations 1 and 3, and headwater station A in the Barren and Green Rivers, 1980. (Data collected with Hess sampler)

Table 18

Taxonomic Composition, Mean Numbers, Mean Biomass, Total Taxa, and Diversity of Macroinvertebrates Collected with a Drift Sampler at Three Stations in the Tailwater below Green River Lake and at One Station Located above the Reservoir, 1979 and 1980

Taxon	Stations: Mean Numbers, No./1000 m^3 1	2*	3	A**
Diptera				
Chironomidae	642	120	120	298
Simuliidae	136	42	139	40
Chaoboridae	868	10	4	106
Trichoptera	324	514	2232	28
Ephemeroptera	47	51	424	973
Plecoptera	2	42	36	278
Coleoptera	5	54	207	23
Oligochaeta	12	4	4	16
Hydracarina	8	417	116	3
Turbellaria	48	0	tr†	0
Terrestrials	28	7	62	78
Other††	3	4	13	44
Total	2123	1265	3357	1887
Mean biomass, mg/1000 m^3	244	232	992	193
Total taxa	25	24	40	29
Shannon-Weaver index	2.14	2.42	2.30	3.68
Number of samples	7	4	6	2

*1979 only.
**Located above reservoir; sampled only in 1980.
†tr = Less than 0.5.
††Includes Corixidae, Megaloptera, Odonata, Lepidoptera, Neuroptera, Gastropoda, Amphipoda, Isopoda, and Decapoda.

numerous. Several other aquatic and terrestrial insect taxa were collected at station A, but none were abundant.

64. Hess. Densities and biomass of the macroinvertebrates collected by this sampling method were similar at all three tailwater stations (Table 19). Total taxa and diversity increased downstream from station 1 to station 3. Highest numbers and biomass, most taxa, and highest diversities were taken at station A, above the reservoir. Station 1 samples were dominated by Chironomidae, Oligochaeta, and Turbellaria, but Trichoptera was also common. Chironomidae remained numerically dominant at stations 2 and 3, but Oligochaeta and Turbellaria declined. Densities of all other major taxa were greater at station 3 than at the other two tailwater stations. Ephemeroptera, Plecoptera, Oligochaeta, Chironomidae, Trichoptera, and Coleoptera were most abundant at station A above the reservoir.

65. Hester-Dendy. Densities and biomass of macroinvertebrates were highest in the immediate tailwater and decreased downstream. Tailwater densities and biomass were higher than those found above the reservoir. Number of taxa and diversity were highest at station 3, followed by stations A, 1, and 2 (Table 20). The taxonomic composition at stations 1 and 2 was similar; Chironomidae, Simuliidae, and Trichoptera were dominant. Turbellaria and Oligochaeta were also moderately abundant at station 1. Downstream, Simuliidae were less abundant, but Chironomidae and Trichoptera continued to be numerous. Ephemeroptera and Plecoptera were both more abundant at station 3 than at the other tailwater stations. The taxonomic composition of the organisms collected above the reservoir consisted primarily of Chironomidae, Ephemeroptera, and Trichoptera.

66. Ordinate analysis and functional groups. Results of the ordination of the 1980 Hess sample data from Green tailwater are presented in Figure 3. Most stations 1 and 3 samples were located in Quadrant III, which suggests that these communities were highly stressed by negative environmental influences. Station A samples were predominately in Quadrants II and IV, which indicates that the macroinvertebrate community at this location

Table 19

Taxonomic Composition, Mean Numbers, Mean Biomass, Total Taxa, and Diversity of Macroinvertebrates Collected with a Hess Sampler at Three Stations in the Tailwater below Green River Lake and at One Station Located above the Reservoir, 1979 and 1980

Taxon	Stations: Mean Numbers, No./m^2			
	1	2*	3	A**
Diptera				
Chironomidae	1,199	1,495	2,250	2,721
Simuliidae	80	43	98	63
Trichoptera	179	796	410	802
Ephemeroptera	42	656	722	4,748
Plecoptera	16	97	264	3,100
Coleoptera	11	11	92	302
Hydracarina	6	86	315	61
Oligochaeta	1,018	97	620	2,760
Turbellaria	1,510	5	244	11
Other†	42	22	22	45
Total	4,103	3,308	5,037	14,613
Mean biomass, mg/m^2	388	355	434	1,255
Total taxa	27	26	37	39
Shannon-Weaver index	2.06	2.34	2.97	3.24
Number of samples	21	12	21	9

*1979 only.
**Located above reservoir; sampled only in 1980.
†Includes Chaoboridae, Ceratopogonidae, Empididae, Tabanidae, Tipulidae, Odonata, Megaloptera, Amphipoda, Isopoda, and Decapoda.

Table 20

Taxonomic Composition, Mean Numbers, Mean Biomass, Total Taxa, and Diversity of Macroinvertebrates Collected with Hester-Dendy Samplers at Three Stations in the Tailwater below Green River Lake and at One Station Located above the Reservoir, 1979 and 1980

Taxon	Stations: Mean Numbers, No./m^2 1	2*	3	A**
Diptera				
Chironomidae	3190	1993	2001	902
Simuliidae	2564	106	26	tr†
Trichoptera	938	514	718	57
Ephemeroptera	38	92	197	306
Plecoptera	0	2	18	tr
Coleoptera	tr	2	4	tr
Oligochaeta	104	7	102	18
Hydracarina	tr	0	0	0
Turbellaria	421	21	116	4
Other††	1	7	20	7
Total	7256	2744	3202	1294
Mean biomass, mg/m^2	1912	547	1143	287
Total taxa	17	12	29	18
Shannon-Weaver index	1.95	1.22	2.21	1.58
Number of samples	12	6	12	4

*1979 only.
**Located above reservoir; sampled only in 1980.
†tr = Less than 0.5.
††Includes Empididae, Megaloptera, Odonata, Collembola, Gastropoda, and Isopoda.

was more typical of that found in natural streams than stations 1 or 3.

67. Collectors and predators were the most numerous feeding types in the river above the reservoir, but scrapers and shredders were also common (Figure 4). At tailwater station 1, macroinvertebrates were almost entirely collectors, whereas at station 3, collectors, predators, and shredders were all common.

Beaver

68. Suction sampler. Densities and biomass of macroinvertebrate fauna were high at station 1, and lower but similar at stations 2 and 4. Diversity was highest at station 1, but numbers of taxa progressively increased downstream from station 1 to station 4 (Table 21). Taxa at station 1 consisted primarily of Amphipoda, Isopoda, Chironomidae, and Oligochaeta. Numbers of Isopoda progressively declined at the downstream stations, but numbers of Amphipoda remained similar. Numbers of Oligochaeta and Chironomidae decreased at station 2, but returned to high levels at station 4.

Hartwell

69. Hess. Density of organisms was highest, but number of taxa and diversity were lowest at station 1 (Table 22). Chironomidae and Oligochaeta were most abundant at all three stations. Chironomidae, Oligochaeta, Hydracarina, Nematoda, Turbellaria, and Amphipoda were more numerous near the dam than downstream. Simuliidae, Trichoptera, and Ephemeroptera were more abundant at station 3. Plecoptera were uncommon at all three stations.

70. Hester-Dendy. Density of organisms was high at station 1, and lower and similar at the other stations (Table 23). Higher numbers in the immediate tailwater were largely a reflection of Oligochaeta densities. Diversity was highest at station 2. Trichoptera and Nematoda were more common at station 1, and Ephemeroptera, Gastropoda, and Hydracarina at the downstream stations.

71. Core. The composition and structure of the macrobenthos were similar at all three stations. Densities and diversities were slightly higher in collections at station 1, whereas numbers of taxa

Table 21

Taxonomic Composition, Mean Numbers, Mean Biomass, Total Taxa, and Diversity of Macroinvertebrates Collected with a Suction Sampler at Three Stations in the Tailwater below Beaver Lake, 1979 and 1980

Taxon	Stations: Mean Numbers, No./m^2 1	2	4
Diptera			
Chironomidae	1061	204	1129
Simuliidae	tr*	3	27
Trichoptera	0	0	1
Ephemeroptera	0	0	3
Plecoptera	0	4	2
Coleoptera	0	0	tr
Hydracarina	6	18	27
Oligochaeta	777	413	742
Nematoda	174	20	59
Turbellaria	78	54	28
Amphipoda	1843	1228	1155
Isopoda	1348	329	205
Other**	tr	tr	1
Total	5287	2273	3379
Mean biomass, mg/m^2	1887	1390	1078
Total taxa	11	12	15
Shannon-Weaver index	2.55	1.93	2.07
Number of samples	23	13	22

*tr = Less than 0.5.
**Includes Tipulidae and Hirudinea.

Table 22

Taxonomic Composition, Mean Numbers, Total Taxa, and Diversity of Macroinvertebrates Collected with a Hess Sampler at Three Stations in the Tailwater below Hartwell Lake, 1979 and 1980

Taxon	Stations: Mean Numbers, No./m^2 1	2	3
Diptera			
Chironomidae	18,460	2,606	4,484
Simuliidae	36	152	262
Trichoptera	126	457	468
Ephemeroptera	358	1,368	1,535
Plecoptera	3	5	5
Hydracarina	589	416	342
Oligochaeta	12,058	3,736	7,046
Nematoda	204	218	152
Turbellaria	218	253	54
Amphipoda	92	175	20
Isopoda	12	0	1
Other*	26	34	11
Total	32,182	9,420	14,380
**			
Total taxa	21	25	24
Shannon-Weaver index	1.36	2.61	2.06
Number of samples	9	9	10

* Includes Ceratopogonidae, Tipulidae, Lepidoptera, Coleoptera, Hemiptera, Gastropoda, Ostracoda, Tardigrada, and Leptodora.

** Mean biomass unavailable.

Table 23

Taxonomic Composition, Mean Numbers, and Diversity of Macroinvertebrates Collected with Hester-Dendy Samplers at Three Stations in the Tailwater below Hartwell Lake, 1979

Taxon	Stations: Mean Numbers, No./m^2 1	2	3
Diptera			
Chironomidae	1466	1240	1444
Simuliidae	2	6	14
Trichoptera	128	8	58
Ephemeroptera	2	47	138
Plecoptera	0	1	0
Hydracarina	25	46	63
Oligochaeta	3174	1240	1263
Nematoda	300	44	8
Turbellaria	85	449	59
Amphipoda	7	11	19
Isopoda	0	0	1
Gastropoda	34	89	77
Other*	2	1	8
Total	5225	3182	3152
**			
Shannon-Weaver index	1.71	2.21	1.82
Number samples	8	10	8

* Includes Chaoboridae, Tipulidae, and Tardigrada.

** Mean biomass unavailable; taxonomic differentiation not comparable with other sites.

were lowest at this location (Table 24). Chironomidae, Oligochaeta, Nematoda, Turbellaria, and Amphipoda were the dominant taxa at all three stations. Oligochaeta, Turbellaria, and Amphipoda decreased in abundance downstream, and Nematoda, Ceratopogonidae, Ephemeroptera, and Tardigrada increased.

72. Substrate sampler. Density, biomass, and total taxa were highest at station 3 (Table 25). Taxa were fewest and diversities lowest at station 1. Most aquatic insect taxa (except Chironomidae) were more abundant at the downstream stations. Chironomidae were present in similar numbers at all three stations. Noninsects, including Hydracarina, Nematoda, and Tardigrada, were also present in higher densities at the downstream sites. Numbers of Oligochaeta were high at all three stations, but not as high at station 2 as at the others. Amphipoda and Turbellaria were most abundant near the dam.

Greeson

73. Hess. Macroinvertebrate densities were highest near the dam, whereas biomass, total taxa, and diversity were higher downstream (Table 26). Larval Diptera (Chironomidae and Chaoboridae) composed all but a small percentage of the aquatic insects collected at station 1; Oligochaeta, Amphipoda, and Nematoda were abundant noninsects. At station 3, the macroinvertebrate fauna was dominated by aquatic insects, including Ephemeroptera, Chironomidae, Plecoptera, and Coleoptera.

Abundance and distribution

74. The abundance and distribution of the eight most common macroinvertebrates collected in the Hess samplers varied by tailwater and station location within tailwaters (Figure 5). Some community differences were also noted among tailwaters of the three project types (flood control, warmwater release; flood control, coldwater release; and hydropower).

75. Chironomidae were most abundant in Pine Creek, Gillham (warmwater flood control), and Hartwell (hydropower); moderately abundant at Barren and Green (coldwater flood control); and least abundant at Beaver and Greeson tailwaters (hydropower). Densities of

Table 24

Taxonomic Composition, Mean Numbers, Total Taxa, and Diversity of Macroinvertebrates Collected with a Core Sampler at Three Stations in the Tailwater below Hartwell Lake, 1979 and 1980

Taxon	Stations: Mean Numbers, No./m^2 1	2	3
Diptera			
Chironomidae	3,742	5,337	2,860
Ceratopogonidae	66	15	169
Simuliidae	0	5	0
Tipulidae	205	22	0
Trichoptera	92	6	56
Ephemeroptera	36	107	174
Hydracarina	288	128	94
Oligochaeta	17,111	11,072	13,597
Nematoda	936	1,227	1,220
Turbellaria	737	336	400
Tardigrada	0	5	51
Amphipoda	432	52	82
Isopoda	16	0	0
Ostracoda	16	20	5
Other*	5	10	6
Total	23,682	18,342	18,714
Total taxa	14	18	18
**			
Shannon-Weaver index	1.70	1.50	1.40
Number of samples	23	23	24

* Includes Chaoboridae, Elmidae, and Gastropoda.
** Mean biomass unavailable.

Table 25

Taxonomic Composition, Mean Numbers, Mean Biomass, Total Taxa, and Diversity of Macroinvertebrates Collected with a Substrate Sampler at Three Stations in the Tailwater below Hartwell Lake, 1979 and 1980

Taxon	Stations: Mean Numbers, No./m^2 1	2	3
Diptera			
Chironomidae	25,182	20,324	24,254
Ceratopogonidae	66	102	320
Simuliidae	65	262	55
Tipulidae	11	306	157
Trichoptera	98	132	215
Ephemeroptera	404	3,379	594
Plecoptera	0	0	146
Odonata	0	0	22
Hydracarina	302	1,144	3,725
Oligochaeta	28,340	15,470	27,269
Nematoda	3,367	4,603	11,275
Turbellaria	306	179	124
Tardigrada	11	142	230
Amphipoda	2,425	306	11
Terrestrial	33	26	36
Total	60,610	46,375	68,433
Mean biomass, mg/m^2	899	777	1,060
Total taxa	13	15	17
Shannon-Weaver index	1.62	2.00	1.95
Number of samples	34	34	34

Table 26

Taxonomic Composition, Mean Numbers, Mean Biomass, Total Taxa, and Diversity of Macroinvertebrates Collected with a Hess Sampler at Two stations in the Tailwater below Lake Greeson, 1979

Taxon	Stations Mean Numbers, No./m^2 1	3
Diptera		
Chironomidae	1387	254
Chaoboridae	24	0
Trichoptera	3	0
Ephemeroptera	3	1150
Plecoptera	3	252
Coleoptera	6	64
Hydracarina	0	120
Oligochaeta	1252	697
Nematoda	101	22
Amphipoda	402	9
Isopoda	24	15
Other*	9	9
Total	3214	2592
Mean biomass, mg/m^2	214	432
Total taxa	16	23
Shannon-Weaver index	1.76	2.35
Number of samples	4	4

*Includes Ceratopogonidae, Tipulidae, and Hirudinea.

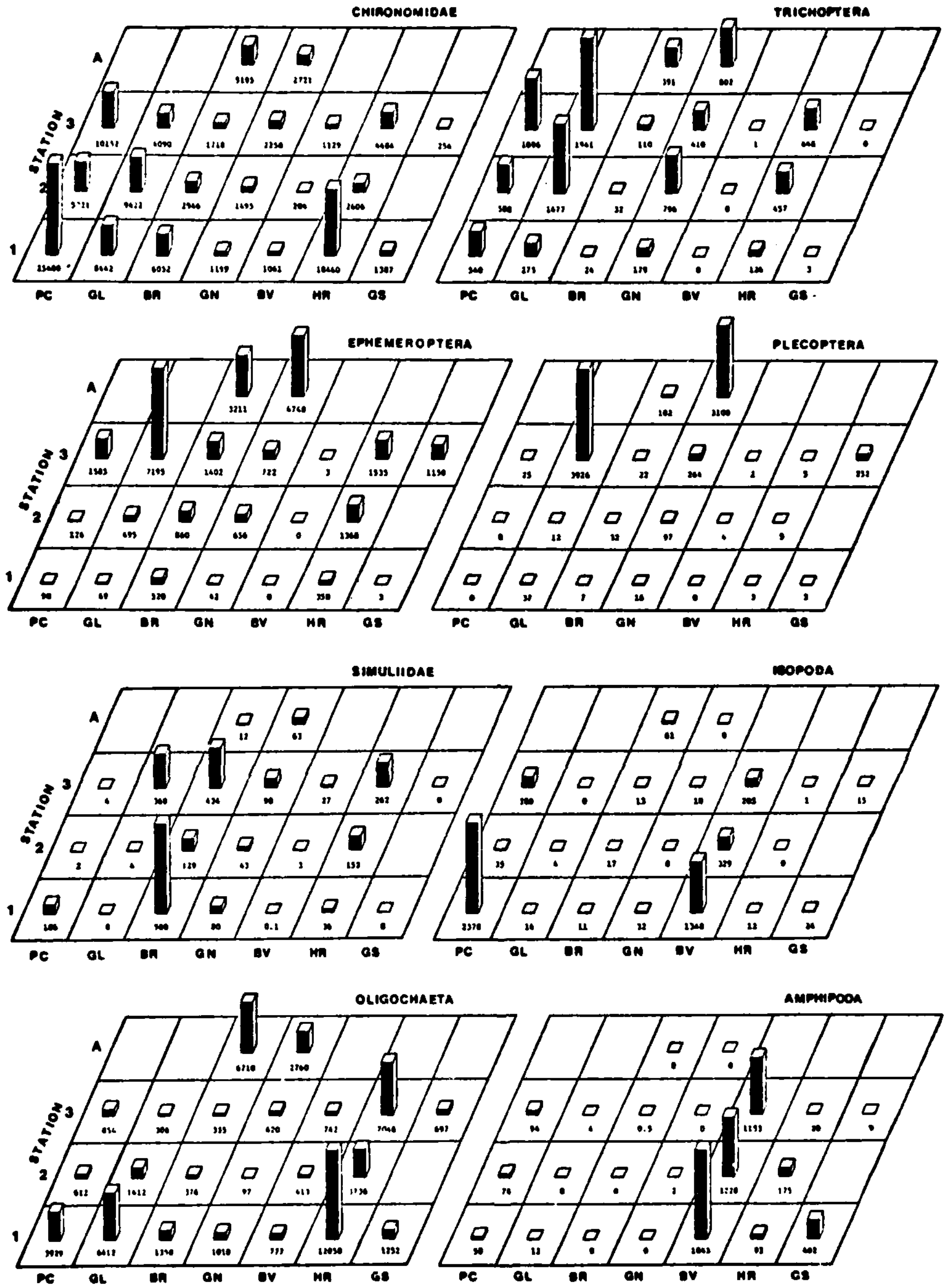

Figure 5. Mean densities (No./m^2) of the eight most common macroinvertebrates collected with Hess samplers at two or three stations in seven tailwaters, 1979 and 1980. Station A samples were taken in the headwaters of Barren and Green reservoirs in 1980. Note that bars are sized to represent density relative to bars only within their particular macroinbertebrate graph (PC - Pine Creek, GL - Gillham, BR - Barren, GN - Green, BV - Beaver, HR - Hartwell, GS - Greeson)

Chironomidae at above-reservoir stations at Barren and Green differed little from their abundance in the corresponding tailwaters. Abundance decreased downstream, from station 1 to station 3, at most locations.

76. Densities of Ephemeroptera were reduced at stations near the dams and increased progressively downstream in all tailwaters. Densities of Ephemeroptera were lowest in the samples collected near the dams at Beaver and Greeson, and highest at Gillham station 3. At Barren and Green, Ephemeroptera were more abundant in the unregulated river than in the tailwater.

77. Densities of Trichoptera (mostly net-spinners) were highest in Pine Creek and Gillham and reduced in the other tailwaters. In most waters, densities increased at downstream stations. More Trichoptera were collected at the above-reservoir stations in Barren and Green than at most tailwater stations.

78. Plecoptera were uncommon in most tailwaters, especially at the stations nearest the dams. They were slightly more abundant in the tailwaters of flood-control than in the hydropower projects. The only tailwater station with high Plecoptera densities was Gillham station 3. Densities were higher in the natural stream above Barren and Green reservoirs than in the tailwater stations.

79. Simuliidae were most abundant in Barren tailwater, but were relatively scarce above the reservoir. They were commonly collected throughout the Green and Hartwell tailwater stations. Populations were variable in the tailwaters of flood-control projects with warmwater release; substantial numbers were collected only at station 1 in Pine Creek and station 3 in Gillham. Simuliidae were uncommon in Beaver and Greeson tailwaters.

80. Oligochaeta were abundant near the dam in all seven tailwaters and reduced at the downstream stations. Densities were highest in Pine Creek, Gillham, and Hartwell tailwaters. Oligochaeta were also abundant in the headwaters above Barren and Green reservoirs.

81. Isopoda were abundant only in Pine Creek and Beaver tailwaters, where densities were highest near the dam and decreased

downstream. No Isopoda were collected above Green River Lake and relatively few were taken above Barren River Lake. Densities were higher in the headwater above Barren River Lake than in the tailwaters.

82. Densities of Amphipoda were low in the tailwaters of all flood control projects; they were not collected at stations above Barren and Green lakes. They were common in the tailwaters of all hydropower projects and most abundant in Beaver tailwater. Densities were highest near the dams and decreased downstream.

83. Hydras were most abundant at station 1, immediately below the dams, in all seven tailwaters (Table 27). Numbers at the downstream stations were either greatly reduced or nil.

Table 27

Abundance of Hydras in Seven Tailwaters, 1979 and 1980

	Stations, No./m^2	
Tailwater	1	3
Pine Creek	7,227	33
Gillham	17,439	61
Barren*	Abundant	Absent
Green*	Abundant	Absent
Beaver*	Abundant	Common
Hartwell	260	38
Greeson	1,627	123

*Hydras were not quantified at Barren, Green, and Beaver tailwaters, but relative abundance was observed by investigators.

Fish

Pine Creek

84. Relative abundance and distribution. Relative abundance of most species was similar in 1979 and 1980 catches by electroshocker, and overall catch rates differed little between years (Appendix D, Tables D1 and D2). The catch rate was 220.7 fish and 25.06 kg/hr in 1979, and 230.6 fish and 23.10 kg/hr in 1980. Longear sunfish and channel catfish were more abundant in 1979 than in 1980, and bluegills and green sunfish were more abundant in 1980 than in 1979. Catch rates for the other species were generally similar between years.

85. Forty-two species of fish were captured in Pine Creek tailwater during 1979 and 1980. The combined catch rate for all species was 226.2 fish/hr weighing 24.17 kg (Table 28). In order of decreasing numerical abundance, the most common fish collected were bluegills, longear sunfish, gizzard shad, white crappies, spotted bass, green sunfish, spotted gar, largemouth bass, and black crappies. Most of the biomass was contributed by spotted gar, channel catfish, largemouth bass, bluegills, golden redhorse, gizzard shad, spotted bass, and white crappies.

86. Fish were more abundant at the station nearer the dam (station 2). Catch rate at this station was 246.2 fish/hr weighing 32.12 kg; whereas downstream (at station 3), the catch rate was 204.0 fish/hr weighing 15.50 kg (Table 28). Species most abundant at the upstream station were bluegills, white crappies, spotted gar, largemouth bass, channel catfish, and spotted sucker; downstream the most common species were longear sunfish, green sunfish, steelcolor shiners, brook silversides, and golden redhorse. The abundance of gizzard shad, spotted bass, black crappies, warmouth, and blackspotted topminnows was similar at the two stations.

87. Angler survey. The 1979 and 1980 angler survey from Pine Creek indicated that white crappies, channel catfish, and largemouth bass were the fish most commonly caught in the tailwater (Table 29). Species taken by anglers in the tailwater and reservoir were similar.

Table 28

Fish Catch per Hour by Electroshocker at Stations 2 and 3 in the Tailwaters below Pine Creek Lake, 1979 and 1980

Species	Stations 2 No./hr	Stations 2 kg/hr	Stations 3 No./hr	Stations 3 kg/hr	Stations Combined No./hr	Stations Combined kg/hr
Chestnut lamprey	0.9	0.01	0.6	0.01	0.8	0.01
Southern brook lamprey			0.2	tr*	0.1	tr
Spotted gar	12.2	6.46	2.8	1.09	7.7	3.90
Longnose gar	0.6	1.72	0.2	tr	0.4	0.90
Bowfin	0.6	0.74			0.3	0.39
Gizzard shad	13.0	1.09	11.4	1.57	12.2	1.32
Common carp	0.2	0.51			0.1	0.27
Emerald shiner			0.4	tr	0.2	tr
Pugnose minnow	0.4	tr	0.6	tr	0.5	tr
Redfin shiner			1.4	tr	0.7	tr
Blacktail shiner			2.8	0.01	1.4	0.01
Mimic shiner			0.2	tr	0.1	tr
Steelcolor shiner	4.3	0.02	8.3	0.05	6.2	0.03
Bluntnose minnow	0.4	tr	1.4	0.01	0.9	tr
Bigmouth buffalo	0.4	0.46			0.2	0.24
Spotted sucker	3.7	1.24	0.6	0.06	2.2	0.68
River redhorse	0.2	0.22	0.8	0.81	0.5	0.50
Black redhorse	0.2	0.04	0.6	0.08	0.4	0.06
Golden redhorse	2.6	1.19	4.9	2.24	3.7	1.69
Yellow bullhead	0.2	0.08			0.1	0.04
Channel catfish	6.8	4.02	3.7	2.20	5.3	3.15
Freckled madtom			0.4	tr	0.2	tr
Flathead catfish	0.6	0.60			0.3	0.31
Blackspotted topminnow	1.9	0.01	3.9	0.01	2.8	0.01
Brook silverside	1.9	tr	5.9	0.01	3.8	tr
Yellow bass	0.9	0.04			0.5	0.02
Green sunfish	4.4	0.18	11.8	0.41	7.9	0.29
Warmouth	4.6	0.19	2.6	0.11	3.7	0.15
Bluegill	87.7	3.23	37.3	1.26	63.7	2.29
Longear sunfish	36.8	0.84	74.1	1.50	54.6	1.15
Redear sunfish	5.0	0.32	1.6	0.12	3.4	.23
Spotted sunfish			0.2	tr	0.1	tr
Spotted bass	10.4	1.49	10.1	1.06	10.3	1.28
Largemouth bass	9.3	3.48	5.9	1.39	7.6	2.48
White crappie	22.8	2.28	0.4	0.02	12.1	1.20
Black crappie	8.7	0.95	5.3	0.66	7.1	0.81
Greenside darter	0.2	tr			0.1	tr
Logperch	3.5	0.05	2.4	0.03	3.0	0.04
Channel darter			0.2	tr	0.1	tr
Slenderhead darter			0.2	tr	0.1	tr
Dusky darter	0.2	tr			0.1	tr
Freshwater drum	0.6	0.66	0.8	0.79	0.7	0.72
Total	246.2	32.12	204.0	15.50	226.2	24.17
Number of species	33		34		42	
Hours fished	5.39		4.93		10.32	

*tr = Less than 0.005.

Table 29

Estimated Average Annual Angling Effort, Harvest, Catch Rate, and Fish Species Captured at Six Tailwaters in 1979 and 1980

Tailwater	Angling Effort	Harvest		Catch Rate		Major Species Captured in Order of Abundance
	Hours	Number	Weight, kg	No./hr	kg/hr	
Pine Creek	15,028	7,548	4,501	0.50	0.30	White crappie Channel catfish Largemouth bass
Gillham	5,867	9,799	1,957	1.67	0.33	Green sunfish Bluegill Longear sunfish Channel catfish
Barren	80,914	19,135	5,619	0.24	0.07	White crappie Rainbow trout White bass
Green	40,554	10,449	4,074	0.25	0.10	White crappie Rainbow trout
Beaver	76,050	23,735	8,030	0.31	0.10	Rainbow trout
Greeson	9,336	7,517	1,739	0.80	0.19	Rainbow trout Bluegill

Large seasonal variations in the tailwater harvest were apparent in both years. Largemouth bass and white crappies were taken primarily in the spring and fall (excluding fall 1980) and channel catfish in the summer. Fish catch, angling effort, and catch rate (number per hour) were all less in 1980 than in 1979.

Gillham

88. Relative abundance and distribution. The relative abundance of most fish species was similar in 1979 and 1980, but overall catch rates were higher in 1979 (Appendix D, Tables D3 and D4). In 1979, the catch rate was 277.9 fish/hr weighing 23.61 kg; in 1980, it was 227.9 fish/hr weighing 18.71 kg. Longear sunfish and gizzard shad were more abundant in 1979; catch rates of other species were similar between years. The weight (kg/hr) of fish captured was slightly higher in 1979 than in 1980 for largemouth bass, golden redhorse, channel catfish, river redhorse, gizzard shad, and spotted bass. The weight of flathead catfish and bluegills was higher in 1980.

89. The catch rate for the 51 species collected in 1979 and 1980 was 246.9 fish/hr weighing 20.57 kg (Table 30). The rank order of decreasing abundance was longear sunfish, bluegills, green sunfish, golden redhorse, spotted bass, gizzard shad, black redhorse, and redfin shiners. Most of the biomass was contributed by largemouth bass, golden redhorse, channel catfish, gizzard shad, black redhorse, spotted bass, and longear sunfish.

90. Fish were most abundant at the upstream tailwater station (station 2). The overall catch at this station was 267.3 fish/hr weighing 26.97 kg; downstream it was 237.9 fish/hr weighing 17.83 kg (Table 30). The catch rate of some species varied between the two stations. Bluegills, black redhorse, largemouth bass, gizzard shad, bluntnose minnows, and white crappies were more abundant upstream, and longear sunfish, spotted bass, and redfin shiners were more abundant downstream. Species that had similar catch rates at both stations were green sunfish, golden redhorse, blackspotted topminnows, channel catfish, and flathead catfish.

Table 30

Fish Catch per Hour by Electroshocker at Stations 2 and 3 in the Tailwaters below Gillham Lake, 1979 and 1980

Species	Station 2 No./hr	Station 2 kg/hr	Station 3 No./hr	Station 3 kg/hr	Stations Combined No./hr	Stations Combined kg/hr
Lamprey species	1.4	0.01	0.2	tr*	0.6	tr
Chestnut lamprey	0.9	0.01	1.2	0.01	1.1	0.01
Southern brook lamprey	1.8	0.01	1.0	0.01	1.2	0.01
Spotted gar	0.9	0.24	1.0	0.44	1.0	0.38
Longnose gar	0.9	0.15	0.6	0.18	0.7	0.17
Bowfin			0.2	0.44	0.1	0.31
Gizzard shad	14.2	1.95	8.3	1.48	10.0	1.62
Chain pickerel			0.2	tr	0.1	tr
Central stoneroller	0.9	tr	2.6	0.01	2.1	0.01
Bigeye shiner			0.4	tr	0.3	tr
Ribbon shiner	0.5	tr	0.2	tr	0.3	tr
Redfin shiner	4.6	0.01	10.2	0.02	8.5	0.02
Steelcolor shiner	1.4	0.02	5.3	0.03	4.1	0.02
Bluntnose minnow	7.8	0.01	2.6	0.01	4.1	0.01
Spotted sucker	1.4	0.21	1.0	0.12	1.1	0.15
River redhorse	0.5	0.44	1.0	1.32	0.8	1.06
Black redhorse	20.5	3.75	3.5	0.66	8.7	1.59
Golden redhorse	16.4	4.00	11.8	3.14	13.2	3.40
Yellow bullhead			0.4	0.01	0.3	0.01
Channel catfish	3.7	1.43	2.8	1.86	3.0	1.73
Freckled madtom			1.2	tr	0.8	tr
Flathead catfish	1.8	0.69	1.2	0.98	1.4	0.89
Pirate perch			0.2	tr	0.1	tr
Northern studfish			0.2	tr	0.1	tr
Blackspotted topminnow	8.2	0.01	6.3	0.01	6.9	0.01
Brook silverside	0.9	tr	5.3	0.01	4.0	tr
White bass	0.5	0.19			0.1	0.06
Yellow bass			3.0	0.08	2.1	0.05
Striped bass			0.2	0.09	0.1	0.06

*tr = Less than 0.005.

(Continued)

Table 30 (Concluded)

Species	Stations 2 No./hr	Stations 2 kg/hr	Stations 3 No./hr	Stations 3 kg/hr	Stations Combined No./hr	Stations Combined kg/hr
Rock bass			0.2	0.04	0.1	0.03
Green sunfish	21.0	0.92	21.6	1.15	21.5	1.08
Warmouth	3.2	0.15	0.8	0.07	1.5	0.09
Bluegill	62.5	1.37	26.6	0.47	37.4	0.74
Longear sunfish	53.4	1.00	80.9	1.61	72.6	1.42
Redear sunfish	3.2	0.21	3.0	0.20	3.0	0.20
Spotted sunfish			0.2	tr	0.1	tr
Smallmouth bass	0.9	0.09	1.2	0.38	1.1	0.29
Spotted bass	5.5	0.69	16.1	1.82	12.9	1.48
Largemouth bass	17.8	9.07	4.3	0.98	8.4	3.42
White crappie	4.1	0.23	0.6	0.04	1.7	0.10
Black crappie	1.4	0.08	1.0	0.14	1.1	0.12
Creole darter			0.2	tr	0.1	tr
Harlequin darter			0.2	tr	0.1	tr
Orangebelly darter			1.6	tr	1.1	tr
Orangethroat darter			0.4	tr	0.3	tr
Speckled darter	0.5	tr			0.1	tr
Logperch	2.3	0.03	3.5	0.03	3.2	0.03
Channel darter	0.9	tr	2.2	tr	1.8	tr
Blackside darter			0.4	tr	0.3	tr
Leopard darter	0.5	tr			0.1	tr
Dusky darter	0.9	tr	1.8	tr	1.5	tr
Total	267.3	26.97	237.9	17.83	246.9	20.57
Number of species	35		48		51	
Hours fished	2.19		5.08		7.27	

91. Angler survey. The 1979 and 1980 angler survey indicated an excellent fishery for sunfishes (green sunfish, bluegills, longear sunfish) and catfishes (channel catfish, flathead catfish, bullheads) in the tailwater during spring (Table 29). Largemouth bass were the most common species taken in the reservoir. The tailwater harvest was dominated by channel catfish in 1979 and by sunfishes in 1980. Angling effort and harvest in the tailwater were less in 1980 than in 1979.

Barren

92. Relative abundance and distribution. Relative abundance of most species was similar in 1979 and 1980; however, overall catch rate in 1979 was roughly double that in 1980. The rate for all species was 60.0 fish and 15.21 kg per hour of electrofishing in 1979, and 123.2 fish and 27.96 kg per hour in 1980 (Appendix D, Tables D5 and D6). The catch of gizzard shad (number per hour) increased from 3.9 in 1979 to 50.2 in 1980, and the weight of common carp increased from 9.40 to 17.10 kg/hr. The relocation of sampling station 1 to nearer the dam in 1980 may have been partly responsible for higher catches.

93. The combined catch rate per hour of electrofishing for the 53 species collected from the tailwater during 1979 and 1980 was 88.1 fish and 20.82 kg (Table 31). The most abundant species were gizzard shad, longear sunfish, common carp, and bluegills. Common carp composed 62 percent of the biomass. Catch rates of game fish (rainbow trout, catfishes, and black basses) were low.

94. Catch rates for all fish combined were higher at station 1 than at either of the other tailwater stations or the above-reservoir station. The combined catch rate per hour was 145.5 fish or 29.86 kg at station 1, 77.2 fish or 13.85 kg at station 2, and 44.0 fish or 17.65 kg at station 3 (Table 31); above the reservoir, these values were 92.5 fish and 21.08 kg. Gizzard shad, longear sunfish, bluegills, white crappies, and spotted suckers were most abundant near the dam, and these species primarily accounted for the higher catch rates at station 1. Rainbow trout were taken only at stations 1 and 2. Catch rates for common carp, spotted bass, and redhorse suckers were similar at all tailwater stations. Catch rates for native stream fishes--

Table 31

Fish Catch per Hour by Electroshocker at Stations 1, 2, and 3 in the Tailwaters below Barren River Lake in 1979 and 1980 and at Station A in Long Creek, a Tributary above the Reservoir, in 1980

Species	Stations 1* No./hr	Stations 1* kg/hr	Stations 2 No./hr	Stations 2 kg/hr	Stations 3 No./hr	Stations 3 kg/hr	Tailwater Stations Combined No./hr	Tailwater Stations Combined kg/hr	Station A No./hr	Station A kg/hr
Longnose gar	0.2	0.12			0.3	0.09	0.2	0.07		
American eel	0.2	0.07	0.1	0.11	tr**	0.03	0.1	0.07		
Gizzard shad	64.5	3.20	4.3	0.55	2.7	0.36	24.4	1.3	19.9	1.85
Rainbow trout	1.1	0.17	0.3	0.03			0.5	0.07		
Grass pickerel									0.5	0.03
Central stoneroller	0.1	tr	0.3	0.01	0.1	tr	0.1	tr	0.4	0.01
Goldfish	0.1	0.04			0.1	tr	0.1	0.01		
Common carp	12.7	17.38	6.9	6.80	10.9	12.93	10.5	12.81	7.2	10.19
Common shiner									1.1	0.08
Emerald shiner	0.4	0.01					0.2	tr		
Spottail shiner					tr	tr	tr	tr		
Silver shiner									1.5	0.01
Rosyface shiner	0.1	tr			0.1	tr	0.1	tr	0.4	tr
Spotfin shiner	0.2	tr			1.7	0.01	0.7	tr	0.8	0.01
Steelcolor shiner	0.1	tr					tr	tr		
Suckermouth minnow					tr	tr	tr	tr		
Bluntnose minnow	0.3	tr			0.7	tr	0.4	tr	1.0	tr
Fathead minnow	0.1	tr			tr	tr	tr	tr	0.1	tr

*Station 1 moved from 2.6 km below dam in 1979 to 1.6 km in 1980.
**tr = Number less than 0.05; weight less than 0.005.

(Continued)

(Sheet 1 of 3)

Table 31 (Continued)

Species	Stations 1 No./hr	Stations 1 kg/hr	Stations 2 No./hr	Stations 2 kg/hr	Stations 3 No./hr	Stations 3 kg/hr	Tailwater Stations Combined No./hr	Tailwater Stations Combined kg/hr	Station A No./hr	Station A kg/hr
River carpsucker	0.5	0.51					0.2	0.18		
Northern hog sucker	0.2	0.01	1.0	0.26	0.8	0.15	0.7	0.13	3.8	0.60
Smallmouth buffalo					tr	0.05	tr	0.02		
Spotted sucker	5.7	1.67	7.2	1.63	0.8	0.23	4.2	1.10	2.1	0.37
Redhorse species			0.1	tr			tr	tr	0.1	0.10
River redhorse	0.3	0.28	0.3	0.36	0.8	1.21	0.5	0.66	0.4	0.41
Black redhorse	1.8	0.94	1.5	0.56	1.0	0.54	1.4	0.69	12.7	2.79
Golden redhorse	0.4	0.18	0.6	0.35	0.4	0.29	0.4	0.27	4.4	1.22
Shorthead redhorse			0.1	0.05	0.7	0.47	0.3	0.20		
Catfish species	0.1	tr					tr	tr		
Yellow bullhead									0.1	0.02
Channel catfish	1.6	1.33	0.5	0.10	0.3	0.09	0.8	0.52	5.1	1.79
Flathead catfish	0.2	0.58					0.1	0.20		
Spring cavefish					tr	tr	tr	tr		
Brook silverside	1.6	tr			0.1	tr	0.6	tr	0.1	tr
White bass	1.0	0.41			tr	0.01	0.4	0.15	0.6	0.13
White bass x striped bass hybrid					tr	tr	tr	tr		
Rock bass	0.4	0.06	1.3	0.14	0.9	0.07	0.8	0.09	1.1	0.09
Green sunfish	0.4	0.01	0.1	tr	0.2	0.01	0.2	0.01	1.9	0.07
Warmouth	1.3	0.07	0.8	0.03	2.2	0.09	1.5	0.06	0.3	0.01
Hybrid sunfish	0.1	0.01	0.1	tr			tr	tr	1.5	0.07
Bluegill	10.7	0.41	9.6	0.40	4.4	0.17	7.9	0.32	18.7	0.57
Longear sunfish	20.5	0.75	32.4	1.11	4.6	0.22	17.6	0.64		
Redear sunfish	0.1	0.01			tr	tr	0.1	tr		
Smallmouth bass			0.1	0.01	0.4	0.03	0.2	0.01		
Spotted bass	5.2	0.68	4.6	0.49	4.6	0.41	4.8	0.52	4.1	0.45
Largemouth bass	0.7	0.47	0.8	0.77	tr	0.01	0.5	0.37	0.6	0.14
White crappie	9.5	0.15	2.3	0.02	3.1	0.06	5.1	0.08	0.2	0.03
Black crappie	2.1	0.14	0.8	0.06	0.8	0.07	1.3	0.09	0.1	0.02

(Continued)

(Sheet 2 of 3)

Table 31 (Concluded)

Species	Stations 1 No./hr	1 kg/hr	2 No./hr	2 kg/hr	3 No./hr	3 kg/hr	Tailwater Stations Combined No./hr	Tailwater Stations Combined kg/hr	A No./hr	A kg/hr
Darter species			0.1	tr			tr	tr		
Greenside darter									0.2	tr
Rainbow darter	0.1	tr			tr	tr	0.1	tr	0.3	tr
Fantail darter			0.1	tr			tr	tr		
Orangethroat darter					tr	tr	tr	tr		
Banded darter			0.1	tr	0.1	tr	0.1	tr		
Logperch	0.4	0.01	0.6	0.01	0.4	0.01	0.4	0.01	0.9	0.01
Slenderhead darter			0.1	tr	0.1	tr	0.1	tr		
Dusky darter	0.1	tr			0.3	tr	0.1	tr		
Freshwater drum	0.4	0.19			tr	0.04	0.2	0.08		
Banded sculpin			0.1	tr	0.4	tr	0.2	tr	0.3	0.01
Total	145.5	29.86	77.2	13.85	44.0	17.65	88.1	20.82	92.5	21.08
Number of species	38		30		43		53		33	
Hours fished	18.20		14.30		20.48		52.98		10.80	

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black redhorse, channel catfish, golden redhorse, and northern hog suckers--were higher above the reservoir than in the tailwater.

95. Angler survey. White crappies, rainbow trout, white bass, sunfishes, and channel catfish were the most common species caught by anglers from the tailwater in 1979 and 1980 (Table 29). One-half of the total harvest was made in the spring. Crappies and trout were captured in all seasons and catfish primarily in the summer. Crappies were common in both the tailwater and reservoir fishery; largemouth bass were taken primarily in the reservoir, and rainbow trout only in the tailwater. About 1500 rainbow trout per month were stocked in the tailwater from April through October and about 32 percent were captured by anglers. Angling effort was high at Barren tailwater in 1979 (86,844 hr) and slightly lower in 1980 (74,985 hr); however, catch per hour was greater in 1980.

Green

96. Relative abundance and distribution. Total catch rates for all species were 120.4 fish or 23.15 kg per hour in 1979, and 160.7 fish or 20.54 kg in 1980 (Appendix D, Tables D7 and D8). Catch rates of white crappies, common carp, and gizzard shad were higher in 1979 than in 1980; those of longear sunfish, bluntnose minnows, northern hog suckers, and central stonerollers were higher in 1980. The abundance of other species was similar in the two years.

97. The combined catch rate by electroshocker for the 64 species captured during 1979 and 1980 was 130.8 fish/hr weighing 22.47 kg (Table 32). The most abundant species were longear sunfish, white crappies, common carp, black redhorse, and northern hog suckers. The weight of fish captured was dominated by common carp (50 percent). Catch rates for channel catfish and most other game fish were low.

98. Overall fish abundance was similar at stations 1 and 3, but the weight of fish captured was greater at station 3. The catch rate per hour for all fish was 148.9 fish or 17.89 kg at station 1, and 139.3 fish or 28.53 kg at station 3 (Table 32). A larger catch of common carp and suckers accounted for the greater weight of the catch at station 3. The catch rates of some fishes varied among stations.

Table 32

Fish Catch per Hour by Electroshocker at Stations 1, 2, and 3 in the Tailwaters below Green River Lake and at Station A in the River above the Reservoir, 1979 and 1980

Species	Stations 1 No./hr	Stations 1 kg/hr	Stations 2* No./hr	Stations 2* kg/hr	Stations 3 No./hr	Stations 3 kg/hr	Tailwater Stations Combined No./hr	Tailwater Stations Combined kg/hr	Station A** No./hr	Station A** kg/hr
Onio lamprey	0.1	tr†					tr	tr		
American brook lamprey					0.1	tr	tr	tr		
Longnose gar	0.1	0.05	0.4	0.06	0.9	0.32	0.5	0.15		
American eel			0.2	0.15	0.1	0.16	0.1	0.10		
Gizzard shad	12.4	1.67	1.1	0.14	3.5	0.58	6.1	0.85	60.1	3.01
Mooneye					0.2	0.04	0.1	0.01		
Rainbow trout	3.8	0.59					1.4	0.22		
Grass pickerel									1.1	0.05
Muskellunge					0.1	tr	tr	tr		
Central stoneroller	3.2	0.04	0.1	tr	2.6	0.01	2.2	0.02	0.7	0.01
Common carp	4.8	5.70	17.3	14.55	17.2	16.35	12.7	11.98	16.2	18.16
Bigeye chub					0.2	tr	0.1	tr		
Streamline chub					0.2	tr	0.1	tr		
Gravel chub					0.4	tr	0.2	tr		
Golden shiner	0.1	tr					tr	tr		
Rosefin shiner					0.1	tr	tr	tr		
Common shiner	0.4	0.02	0.5	0.02	0.8	0.02	0.6	0.02	0.7	0.03

*Sampled only in 1979.
**Sampled only in 1980.
†tr = Number less than 0.05; weight less than 0.005.

(Continued)

(Sheet 1 of 3)

Table 32 (Continued)

Species	Stations 1 No./hr	Stations 1 kg/hr	Stations 2 No./hr	Stations 2 kg/hr	Stations 3 No./hr	Stations 3 kg/hr	Tailwater Stations Combined No./hr	Tailwater Stations Combined kg/hr	Station A No./hr	Station A kg/hr
Spottail shiner					0.1	tr	tr	tr		
Silver shiner	0.5	tr			0.1	tr	0.2	tr		
Rosyface shiner					0.2	tr	0.1	tr	0.2	tr
Spotfin shiner	0.4	tr	0.7	tr	2.0	0.01	1.1	0.01		
Suckermouth minnow					0.9	tr	0.3	tr	0.5	tr
Bluntnose minnow	1.8	0.01	4.8	0.01	11.9	0.02	6.3	0.01	0.7	tr
Creek chub					0.1	tr	tr	tr		
White sucker	0.1	0.04					tr	0.01		
Northern hog sucker	5.1	0.81	1.7	0.27	11.9	1.53	6.6	0.93	7.5	0.91
Spotted sucker	0.6	0.14	2.6	0.70	2.5	0.06	1.8	0.26	7.1	0.07
Silver redhorse			0.3	0.19	0.1	0.08	0.1	0.08	0.7	0.18
Redhorse species	3.3	1.15	0.8	0.32			1.4	0.42		
River redhorse					0.2	0.13	0.1	0.05		
Black redhorse	9.5	2.94	2.4	0.67	8.2	2.80	7.1	2.27	37.3	4.96
Golden redhorse	0.1	0.04	1.5	0.60	5.2	1.95	2.3	0.89	14.9	2.98
Shorthead redhorse	0.7	0.26	0.2	0.04	4.0	1.13	1.8	0.52	3.9	0.94
Yellow bullhead									0.2	0.04
Channel catfish	0.4	0.19	1.1	0.44	0.6	0.21	0.7	0.26	9.1	2.06
Flathead catfish	0.2	0.25	0.1	0.06	0.1	0.11	0.1	0.15	0.5	4.05
Northern studfish					0.2	tr	0.1	tr		
Brook silverside	0.1	tr					tr	tr	0.9	tr
White bass	0.6	0.07			0.1	0.03	0.2	0.04	1.4	0.52
Rock bass	5.5	0.84	4.8	0.42	5.7	0.55	5.4	0.62	0.5	0.05
Green sunfish	0.7	0.02	0.1	0.01			0.3	0.01	1.4	0.06
Warmouth			0.2	tr	0.6	0.03	0.3	0.01	2.3	0.08
Bluegill	2.8	0.12	1.3	0.04	2.1	0.07	2.2	0.08	5.0	0.19
Longear sunfish	9.1	0.39	29.7	0.89	43.4	1.46	27.2	0.92	23.1	0.59
Smallmouth bass	6.5	0.20	0.3	tr	0.6	0.12	2.7	0.12	0.2	0.19
Spotted bass	3.1	0.09	2.6	0.14	2.8	0.17	2.8	0.13	6.4	0.79
Largemouth bass			0.3	0.16	0.7	0.13	0.4	0.09		
White crappie	54.9	1.97	16.1	0.84	3.8	0.22	25.7	1.03	8.2	0.49

(Continued)

(Sheet 2 of 3)

Table 32 (Concluded)

Species	Stations 1 No./hr	Stations 1 kg/hr	Stations 2 No./hr	Stations 2 kg/hr	Stations 3 No./hr	Stations 3 kg/hr	Tailwater Stations Combined No./hr	Tailwater Stations Combined kg/hr	Station A No./hr	Station A kg/hr
Orangefin darter					0.2	tr	0.1	tr		
Greenside darter	6.0	0.03	0.1	tr	0.5	tr	2.4	0.01		
Rainbow darter	5.0	0.01	0.3	tr	0.7	tr	2.2	tr		
Fantail darter			0.1	tr	0.1	tr	0.1	tr		
Stripetail darter					0.1	tr	tr	tr		
Johnny darter					0.1	tr	tr	tr		
Speckled darter					0.3	tr	0.1	tr		
Banded darter	0.1	tr			0.2	tr	0.1	tr		
Logperch	5.0	0.08	2.5	0.03	1.3	0.02	3.0	0.04	1.4	0.01
Channel darter	0.7	tr	0.2	tr	0.2	tr	0.4	tr		
Gilt darter	0.1	tr	0.1	tr	0.3	tr	0.2	tr		
Blackside darter					0.1	tr	tr	tr		
Slenderhead darter			0.5	tr	0.2	tr	0.2	tr		
Dusky darter					0.2	tr	0.1	tr	0.2	tr
Sauger	0.2	0.11					0.1	0.04		
Walleye					0.1	0.14	tr	0.05		
Freshwater drum	0.1	0.04	0.1	0.08	0.1	0.08	0.1	0.06		
Banded sculpin	0.8	0.02			0.1	tr	0.3	0.01		
Total	148.9	17.89	95.1	20.53	139.3	28.53	130.8	22.47	212.4	40.42
Number of species	38		34		56		64		29	
Hours fished	16.17		11.97		16.26		44.40		4.37	

(Sheet 3 of 3)

Species more common at station 1 than at 3 were white crappies, gizzard shad, smallmouth bass, and rainbow trout. Darters and logperch were also more common at station 1, but differences in water clarity between stations probably biased capture efficiency for these fish. Species most abundant at station 3 were longear sunfish, common carp, bluntnose minnows, northern hog suckers, and golden redhorse. Common carp and black redhorse composed most of the biomass at both stations. Abundance of rock bass and spotted bass was similar at all stations. The catch rates of several fishes, including gizzard shad, suckers, and catfishes were higher above the reservoir (station A) than at the tailwater stations.

99. Angler survey. White crappies and rainbow trout were the most common fish taken by anglers at Green River Lake tailwater in 1979 and 1980 (Table 29), and white crappies and largemouth bass were taken most frequently in the reservoir. Approximately 1500 rainbow trout were stocked in the tailwater each month from April through October and about 25 percent were captured by anglers. Most tailwater fish were harvested in the spring, but angling effort was high throughout spring and summer. Angler effort was higher in 1979 (46,146 hr) than in 1980 (34,962 hr), but catch per hour was greater in 1980.

Beaver

100. Relative abundance and distribution. The combined catch rate by electroshocker for 22 fish species in 1979 and 1980 was 43.4 fish/hr (Table 33). Eight additional species were seen, but because of their abundance in catches by electroshocker no attempt was made to quantitatively collect them. Included here were gizzard shad, common shiners, largescale stonerollers, Ozark minnows, mottled sculpins, brook silversides, white bass, and logperch. Catch rates could not be calculated for these species, but the mottled sculpin appeared to be the most abundant fish in the tailwater. These species are not discussed further, but all were listed as abundant in Beaver tailwater in Appendix E, Table E1.

101. Rainbow trout was the only abundant game fish captured (33.6 fish/hr). About 1400 rainbow trout were stocked in the tailwater

Table 33

Number of Fish Captured per Hour by Electroshocker at Stations 2, 3, and 4 in the Tailwaters below Beaver Lake, 1979 and 1980

Species	Stations: No./hr 2	3*	4	Stations Combined No./hr
Longnose gar		0.1	0.4	0.1
Gizzard shad	**	**	**	**
Rainbow trout	50.6	24.5	7.2	33.6
Largescale stoneroller	**	**	**	**
Common carp	2.1	1.1	5.5	2.8
Common shiner	**		**	**
Ozark minnow	**	**	**	**
Steelcolor shiner	tr†			tr
Quillback			2.0	0.5
White sucker	0.1		0.2	0.1
Northern hog sucker	tr		2.0	0.5
River redhorse			0.1	tr
Black redhorse	0.2		0.1	0.1
Golden redhorse	2.6	0.7	3.6	2.4
Channel catfish			0.1	tr
Brook silverside	**		**	**
White bass			**	**
Green sunfish	0.8	0.2		0.5
Bluegill	0.9	0.1	2.3	1.1
Longear sunfish	0.1		0.3	0.1
Redear sunfish			0.1	tr
Spotted bass	tr		1.6	0.4
Largemouth bass	0.4		0.6	0.4
White crappie	0.2			0.1
Black crappie	0.3		0.4	0.2
Walleye			0.2	0.1
Logperch	**	**	**	**
Darter species			1.4	0.4
Mottled sculpin	**	**	**	**
Banded sculpin	tr			tr
Total	58.3	26.7	28.1	43.4
Number of species	22	11	26	30
Hours fished	26.21	11.42	12.83	50.46

*Station only sampled in 1979.
**Species observed but not collected.
†tr = Less than 0.05.

each week from April through October. Common carp, suckers, channel catfish, and sunfishes were infrequently caught. Electrofishing catch rates for fish quantitatively collected in 1979 and 1980 were 35.6 and 52.6 fish/hr (Appendix D, Tables D9 and D10). Rainbow trout made up most of the catch in both years. Rainbow trout and common carp were slightly more abundant in 1980 than in 1979. Rainbow trout were most abundant near the dam (station 2) and least abundant downstream (station 4). Suckers and sunfishes appeared to be uniformly distributed among the tailwater stations.

102. Angler survey. On the basis of the tailwater angler survey, it was estimated that an average of 23,735 rainbow trout were harvested in 76,050 hours of fishing in 1979 and 1980 (Table 29). About 50,000 trout were stocked in this tailwater each year. Anglers caught about 55 percent of these fish; 6 to 19 percent were taken within 24 hours after they were stocked. Most fish were harvested in fall in 1979 and in summer in 1980. Beaver reservoir supported primarily a white crappie and largemouth bass fishery.

Hartwell

103. Relative abundance and distribution. The relative abundance of some species varied between 1979 and 1980. The catch rate for all fish in 1979 was 65.4 fish/hr weighing 17.99 kg, and in 1980 it was 100.8 fish/hr weighing 13.85 kg (Appendix D, Tables D11 and D12). The catch of spottail shiners was 37 fish/hr greater in 1980. The weight of gizzard shad, rainbow trout, brown trout, common carp, silver redhorse, and smallfin redhorse captured was slightly greater in 1979 than in 1980. The trouts and redbreast sunfish were the most abundant game fish in both years; catch rates of other game fish, including catfishes and black basses, were low in both years.

104. The combined catch rate by electroshocker for 35 species in 1979 and 1980 was 78.7 fish/hr weighing 16.43 kg (Table 34). The most abundant species were spottail shiners, redbreast sunfish, rainbow trout, green sunfish, bluegills, silver redhorse, and brown trout. Common carp, silver redhorse, rainbow trout, smallfin redhorse, brown trout, and spotted suckers composed most of the biomass.

Table 34

Fish Catch per Hour by Electroshocker at Stations 1, 2, and 3 in the Tailwaters below Hartwell Lake, 1979 and 1980

Species	Stations 1 No./hr	1 kg/hr	2 No./hr	2 kg/hr	3 No./hr	3 kg/hr	Stations Combined No./hr	Stations Combined kg/hr
Gizzard shad	0.1	0.04	3.1	0.84	1.6	0.44	1.6	0.43
Threadfin shad	0.1	tr*					tr	tr
Rainbow trout	14.1	1.83	6.2	0.85	0.6	0.16	6.7	0.92
Brown trout	8.1	1.42	2.9	0.81	0.4	0.29	3.7	0.81
Chain pickerel	0.4	0.12	0.1	0.01			0.1	0.05
Common carp	0.3	0.65	3.0	8.13	2.1	5.57	1.8	4.71
Bluehead chub	0.3	0.02			0.3	0.02	0.2	0.01
Golden shiner			0.1	tr			tr	tr
Spottail shiner	9.6	0.11	56.5	0.74	20.4	0.29	27.6	0.37
Whitefin shiner	1.2	0.01	0.6	tr	0.1	tr	0.6	tr
Quillback			0.1	0.17	0.2	0.24	0.1	0.14
Creek chubsucker	0.6	0.06	0.5	0.04	0.1	tr	0.4	0.03
Northern hog sucker	0.1	0.04	2.9	0.84	2.6	0.64	1.9	0.50
Spotted sucker	0.9	0.46	0.5	0.44	1.3	1.30	0.9	0.77
Silver redhorse	0.1	tr	4.8	5.81	7.8	7.16	4.4	4.41
Smallfin redhorse	0.1	0.02	1.0	0.72	4.0	2.12	1.8	1.01
Snail bullhead			0.9	0.06	0.2	0.01	0.3	0.02
White catfish	0.1	0.01	0.4	0.06	0.2	0.03	0.3	0.03
Brown bullhead	0.4	0.04	3.3	0.37	0.9	0.13	1.4	0.17
Flat bullhead			0.2	0.01	0.1	tr	0.1	tr

*tr = Number less than 0.05; weight less than 0.005.

(Continued)

Table 34 (Concluded)

Species	Stations 1 No./hr	Stations 1 kg/hr	Stations 2 No./hr	Stations 2 kg/hr	Stations 3 No./hr	Stations 3 kg/hr	Stations Combined No./hr	Stations Combined kg/hr
White bass	0.1	0.02	0.5	0.11	0.1	0.02	0.2	0.05
White bass x striped bass hybrid			0.2	0.04	0.1	0.08	0.1	0.04
Striped bass					0.1	0.01	tr	tr
Sunfish species	0.1	tr			0.2	0.01	0.1	0.01
Redbreast sunfish	10.4	0.62	13.9	0.80	8.9	0.79	10.9	0.74
Green sunfish	3.4	0.15	6.4	0.10	5.0	0.17	4.9	0.14
Pumpkinseed	0.1	tr					tr	tr
Warmouth	0.2	tr	0.3	0.02	0.3	0.01	0.3	0.01
Bluegill	4.6	0.28	2.0	0.13	6.2	0.42	4.4	0.29
Redear sunfish	0.1	0.02					tr	0.01
Spotted sunfish			0.2	tr	0.1	tr	0.1	tr
Largemouth bass	1.1	0.41	0.4	0.05	1.4	0.73	1.0	0.42
Yellow perch	0.5	0.03	1.4	0.13	4.8	0.64	2.4	0.29
Blackbanded darter	0.1	tr	0.5	tr	0.7	tr	0.4	tr
Walleye	0.1	0.05	0.1	0.10			tr	0.05
Total	57.3	6.41	113.0	21.38	70.8	21.28	78.7	16.43
Number of species	28		29		29		35	
Hours fished	14.01		12.66		15.91		42.58	

105. Fish were least abundant near the dam (57.3 fish or 6.41 kg per hour). Hourly catch rates downstream were 113.0 fish or 21.38 kg at station 2 and 70.8 fish or 21.28 kg at station 3 (Table 34). Rainbow trout and brown trout were most abundant at station 1, near the dam; spottail shiners, silver redhorse, yellow perch, common carp, northern hog suckers, and smallfin redhorse were most abundant downstream at stations 2 and 3. The abundance of redbreast sunfish, green sunfish, bluegills, and largemouth bass did not vary substantially among the three tailwater stations.

Greeson

106. Relative abundance and distribution. The catch rate by electroshocker for the 48 species collected in this tailwater in 1979 was 210.0 fish/hr weighing 50.27 kg (Table 35). The most abundant fishes were longear sunfish, bluegills, common carp, bluntnose minnows, golden redhorse, green sunfish, and gizzard shad. Common carp, golden redhorse, bowfins, gizzard shad, chain pickerel, longear sunfish, largemouth bass, and bluegills made up most of the weight of fish captured (common carp alone contributed 58 percent). Catch rates for catfishes and most other game fish were low in this tailwater.

107. Catch rates for all species combined were highest at station 3, and lower and similar at stations 1 and 2. The hourly catch rates for all fish at stations 1, 2, and 3 were 194.9 fish or 41.76 kg; 195.2 fish or 44.66 kg; and 250.2 fish or 67.74 kg. Station 3 catch rates were highest because of the numerical abundance of longear sunfish and the greater weight of common carp.

108. The abundance of several species varied among tailwater stations (Table 35). Numbers of rainbow trout, Kiamichi shiners, bluntnose minnows, and logperch and weights of rainbow trout, bluegills, and largemouth bass were greatest at station 1. Rainbow trout were captured only at stations 1 and 2. Longear sunfish and golden redhorse were most abundant at stations 2 and 3. Common carp were most abundant at station 3, but large numbers also occurred at stations 1 and 2. Species whose catch rates did not vary substantially among tailwater

Table 35

Fish Catch per Hour by Electroshocker at Stations 1, 2, and 3 in the Tailwaters below Lake Greeson, 1979

Species	Station 1		Station 2		Station 3		Stations Combined	
	No./hr	kg/hr	No./hr	kg/hr	No./hr	kg/hr	No./hr	kg/hr
Chestnut lamprey	0.8	0.01	0.9	0.02			0.6	0.01
Southern brook lamprey			0.9	0.01			0.4	tr*
Spotted gar			0.9	0.40	3.8	1.76	1.5	0.67
Longnose gar					0.8	tr	0.2	tr
Bowfin			3.2	7.27			1.5	3.33
American eel	0.8	0.10	0.9	0.53			0.6	0.27
Gizzard shad	10.4	2.17	1.9	0.51	17.7	4.17	8.5	1.96
Rainbow trout	5.6	1.21	0.5	0.23			1.7	0.43
Grass pickerel			0.5	tr			0.2	tr
Chain pickerel	2.4	2.34	1.4	1.72	1.5	0.22	1.7	1.47
Common carp	14.4	20.54	13.4	19.85	42.3	52.51	21.7	29.05
Emerald shiner					1.5	0.01	0.4	tr
Bigeye shiner			9.3	0.03	3.8	tr	5.3	0.02
Kiamichi shiner	12.0	0.02					3.2	0.01
Redfin shiner	3.2	0.01	2.8	0.01	8.5	0.01	4.5	0.01
Bluntnose minnow	26.3	0.07	11.1	0.03	5.3	0.01	13.6	0.03
Creek chubsucker	1.6	0.16					0.4	0.04
Northern hog sucker	3.2	0.68	0.9	0.19	1.5	0.22	1.7	0.33
Spotted sucker	5.6	2.23			3.1	0.76	2.3	0.80
River redhorse			0.5	1.37			0.2	0.63
Golden redhorse	3.2	1.16	13.9	4.90	16.2	4.44	11.7	3.78

*tr = Less than 0.005.

(Continued)

Table 35 (Concluded)

Species	Station 1 No./hr	Station 1 kg/hr	Station 2 No./hr	Station 2 kg/hr	Station 3 No./hr	Station 3 kg/hr	Stations Combined No./hr	Stations Combined kg/hr
Yellow bullhead					0.8	0.18	0.2	0.05
Channel catfish			0.5	1.05			0.2	0.48
Flathead catfish			0.5	0.34			0.2	0.16
Pirate perch			0.9	0.01	1.5	0.01	0.8	tr
Blackspotted topminnow	0.8	tr	13.0	0.04	0.8	tr	6.4	0.02
Brook silverside			0.5	tr	0.8	tr	0.4	tr
Green sunfish	7.2	0.41	19.0	1.65			10.6	0.86
Warmouth			2.3	0.21	0.8	tr	1.3	0.10
Orangespotted sunfish					0.8	tr	0.2	tr
Bluegill	31.9	2.99	19.0	0.61	30.8	0.59	25.7	1.24
Longear sunfish	28.7	1.07	63.5	1.29	80.8	1.63	59.0	1.33
Redear sunfish	0.8	0.03					0.2	0.01
Spotted bass	4.8	1.86	3.7	0.78	3.1	0.28	3.8	0.93
Largemouth bass	7.2	3.42	4.2	0.58	8.5	0.42	6.2	1.29
White crappie			0.5	0.12			0.2	0.06
Black crappie	4.0	0.88	2.3	0.41	3.1	0.50	3.0	0.56
Greenside darter	1.6	tr			3.8	0.01	1.5	tr
Creole darter	4.8	0.01					1.3	tr
Harlequin darter					0.8	tr	0.2	tr
Orangebelly darter	4.8	0.01					1.3	tr
Speckled darter					0.8	tr	0.2	tr
Banded darter					0.8	tr	0.2	tr
Logperch	8.0	0.02	0.9	0.01	2.3	0.01	3.2	0.01
Channel darter					3.1	tr	0.8	tr
Blackside darter			0.9	tr	0.8	tr	0.6	tr
Walleye			0.5	0.49			0.2	0.23
Freshwater drum	0.8	0.36					0.2	0.10
Total	194.9	41.76	195.2	44.66	250.2	67.74	210.0	50.27
Number of species	26		32		30		48	
Hours fished	1.25		2.16		1.30		4.71	

stations were chain pickerel, redfin shiners, northern hog suckers, spotted bass, and black crappies.

109. Angler survey. The 1979 and 1980 angler surveys from Greeson tailwater indicated seasonal fisheries for rainbow trout and bluegills (Table 29). Bluegills were caught primarily in fall and trout in spring and summer. Trout made up 67 percent of the total angler catch in 1979 and about 84 percent in 1980. Greeson reservoir supported a largemouth bass and crappie fishery. Angling effort and harvest were greater in 1979 than in 1980.

PART V: DISCUSSION

Flood-Control Projects

Warmwater release

110. The physicochemical characteristics of Pine Creek and Gillham tailwaters were generally similar in 1979 and 1980. Flows were maintained at minimum levels throughout both summers in Pine Creek tailwater despite abnormally high rainfall in 1979; in Gillham tailwater, minimum low flows were exceeded on a number of occasions during the summer of 1979 because of flood releases. Flows at Gillham were at or near minimum for most of the summer in 1980. Summer water temperatures were high in both tailwaters (30.0°C in Pine Creek and 32.0°C in Gillham), and dissolved oxygen concentrations were generally above 5.0 mg/ℓ despite the withdrawal of water from anoxic areas of the reservoir. Conductivity, alkalinity, and particulate matter were low in both tailwaters. Iron concentrations exceeded the EPA criterion for freshwater life (1.0 mg/ℓ) during late summer or fall in both tailwaters (U. S. Environmental Protection Agency 1976). Manganese concentrations in Pine Creek tailwater exceeded 1.0 mg/ℓ in late summer, whereas those in Gillham tailwater never exceeded 0.4 mg/ℓ. Both Pine Creek and Gillham reservoirs are located in an area where geochemical leaching may increase the amount of iron and manganese available to the watershed. The higher iron and manganese concentrations observed in 1979 were presumably the result of increased organic runoff during the high water year and increased levels of decomposition in the reservoirs. The extended anaerobic conditions that occurred caused greater amounts of iron and manganese to be released in the tailwater discharge, particularly in Pine Creek.

111. The warmwater discharges at Pine Creek and Gillham produced a relatively dense macroinvertebrate fauna; taxonomic composition and distribution were similar in the two tailwaters. Densities and biomass of organisms were generally highest near the dams and decreased downstream, whereas diversities and numbers of taxa were lowest near the

dams and increased downstream. Larval Diptera (including Chaoboridae flushed from the reservoirs) and Oligochaeta were dominant near the dams, and Trichoptera, Ephemeroptera, Plecoptera (Gillham only), and Chironomidae were dominant downstream. Isopoda were also abundant in the tailwater immediately below Pine Creek reservoir because the habitat was suitable there. Extended seasonal flood releases, together with increased levels of iron and manganese, may have limited benthic invertebrate diversities in the immediate tailwaters. The progressive increase in macroinvertebrate diversities at the downstream stations probably resulted from more variable habitat and a moderation in the effects of flood releases.

112. The fish communities of Pine Creek and Gillham tailwaters were similar in species composition and relative abundance. Sunfishes, suckers, and catfishes dominated the fish populations in both tailwaters, and fish were most abundant at the upriver station nearest the dam. Blockage of upstream migration, fish passage through the dam, and variation in habitat type and availability between tailwater stations may have resulted in upriver concentration of fish. Species composition was similar at upstream and downstream stations within the tailwaters, but the relative abundance of some species varied by station. Bluegills and white crappies (typical reservoir inhabitants) were more abundant upstream and longear sunfish (typical river inhabitant) was more abundant downstream at both tailwaters. Fish distribution and relative abundance did not differ substantially in 1979 and 1980, despite large differences in reservoir discharge during the two years.

113. In summary, the primary physical and chemical conditions encountered in tailwaters of flood-control projects with warmwater release included seasonally altered flows and high concentrations of iron and manganese during reservoir stratification. Invertebrates in the immediate tailwaters were affected by the reservoir discharge, but those 12 to 15 km downstream had recovered and the species distribution resembled that of a more natural stream community (Ward 1976). In general, the relatively immobile invertebrate community appeared to be

more sensitive to environmental changes caused by the dams than were fish populations. Fish were usually more abundant at the station near the dams than downstream.

Coldwater release

114. The physicochemical characteristics of the tailwaters below Barren River and Green River reservoirs were generally similar in 1979 and 1980. Flows in both tailwaters were maintained at their established minimums during the summer of 1980, but releases consistently exceeded minimum levels in 1979 as a result of above-normal precipitation.

115. Low water temperatures necessary for trout ($\leq$21°C) were, at best, marginally maintained in these tailwaters. Extended flood releases in 1979 depleted the hypolimnion of cold water in both reservoirs. Tailwater temperatures immediately below the dams exceeded 21°C during most of the summer. In 1980, sufficient cold water was stored in the hypolimnion of Green River reservoir to allow tailwater temperatures to be maintained below 21°C throughout the summer. However, release of water from upper level bypass gates allowed tailwater temperatures to exceed 21°C in June and July. Temperatures in August and September were maintained at or below 21°C. At Barren River, tailwater temperatures exceeded 21°C during most of July and all of August and September, despite the withdrawal of water from the deepest level of the two-level bypass gates. Maintenance of low water temperatures appears possible under normal circumstances in the Green River tailwater but not in the Barren River tailwater. Summer water temperatures in both tailwaters increased downstream as a result of solar warming.

116. Dissolved oxygen levels were never less than 6.0 mg/ℓ in either tailwater in samples taken at minimum flow. Elevated levels of iron and manganese occurred periodically in both tailwaters in 1979 and 1980 because of the release of water from the anoxic hypolimnion of the reservoirs. Weekly samples taken in the immediate tailwater of both dams during the summer of 1980 indicated that levels of ammonia, iron, and manganese were generally highest in October, but that

elevations also occasionally occurred in August and September. Reasons for the fluctuations in concentration of iron, manganese, and ammonia are unknown but are probably related to reservoir biogeochemistry and reservoir operations.

117. Macroinvertebrate samples collected in the rivers above Barren and Green reservoirs enabled comparison of communities in the cold tailwaters with those in the unaltered streams. The effects of the reservoir discharges were generally similar in both tailwaters--diversity and numbers of taxa were lowest near the dam (stations 1 and 2) and highest at the downstream station. Densities and biomass of organisms did not vary substantially among tailwater stations. (High numbers and biomass in the drift at station 2 in 1979 reflected a sampling aberration caused by an influx of Chaoboridae from the reservoir on one occasion shortly after placement of the sampler). Diversity, numbers of taxa, density of organisms, and biomass were greatest in Hess samples collected at the above-reservoir stations. Diversity and total numbers of taxa in the stream drift were also higher above the reservoir than in the tailwaters. Lower densities and biomass were recorded above the reservoir than below because of the addition of substantial quantities of Chaoboridae into the tailwater drift from the reservoir.

118. The environmental differences at each station were also reflected in the taxonomic composition of the invertebrate communities. At station 1 in both Barren and Green tailwaters, Chironomidae, Simuliidae, Chaoboridae, filter-feeding Trichoptera, and Turbellaria were most common. Downstream, the more diverse habitat and the gradual return to a more natural stream environment resulted in increased taxonomic diversity, decreased total numbers, and a shift in the taxonomic composition. Plecoptera, Ephemeroptera, and Coleoptera increased in abundance, whereas Simuliidae, Chaoboridae, and Turbellaria were reduced or eliminated. The taxonomic composition at station 2 was transitional, and had characteristics of both stations 1 and 3. The many different taxa, high diversities, and high densities

of invertebrates above both reservoirs were indicative of unregulated stream communities at these locations.

119. Ordination analyses provided additional evidence of the influence of reservoir releases on tailwater benthos. The macroinvertebrate communities at the stations nearest the dams were apparently modified by environmental stress caused by reservoir discharge. In contrast, samples from above the reservoirs consistently exhibited the characteristics of natural stream communities (Ward 1976). The tailwater stations farthest downstream were less affected than those near the dams, which indicates some reduction in environmental stress.

120. Comparison of the functional feeding types (collector, shredder, scraper, and predator) at the three locations sampled in the headwaters and tailwaters of both Barren and Green reservoirs in 1980 indicated that stations could be separated into three distinct zones similar to those identified by the ordination analysis. All four functional groups were well represented at the stations above the reservoirs, indicating a natural unstressed community (Hocutt 1975). Few organisms, other than collectors, were found in the immediate tailwaters, indicating that the trophic status of that community was unbalanced (Cummins and Spengler 1978). At the downstream tailwater stations, collectors remained dominant, but predators and shredders were also present. The downstream tailwater station appeared to be transitional between the highly stressed communities near the dams and the natural communities above the reservoirs.

121. Species composition and relative abundance of fishes were similar in Barren and Green tailwaters. Population biomass in both tailwaters was dominated by rough fish (carp and suckers); populations of catchable-sized game fish (black basses, rainbow trout, and catfishes) were small. In both tailwaters, relative abundance of most fish species changed little between 1979 and 1980. Among the many species abundant in the reservoirs (unpublished data, Kentucky Department of Fish and Wildlife Resources, Bowling Green) that were also abundant in the tailwaters were gizzard shad, common carp, spotted suckers, bluegills, and white crappies. Recent studies (East Central

Reservoir Investigations, Bowling Green, Kentucky) indicate that some of these fish, particularly gizzard shad, white crappies, and bluegills, passed through the dam and remained in the tailwaters. Other studies have also shown that reservoirs are the source of many fish found in tailwaters (Carter 1969, Walburg et al. 1971, Hanson 1977).

122. Fish abundance differed among the Barren and Green sampling stations. Fish were most abundant at station 1 in Barren tailwater, but were equally abundant at stations 1 and 3 in Green tailwater. Fish occurrence at station 1 in both tailwaters appeared to be related to fish passage through the dam and the quantity of available habitat. Sparse habitat (little brush and log cover) at station 1 in Green tailwater limited abundance, but fish habitat at Barren station 1 was plentiful. Rainbow trout were restricted to upstream stations (station 1 and 2 in Barren and station 1 in Green), within the limits of coldwater releases from the dams. Low water temperatures at station 1 may have adversely affected some native river fish (e.g., channel catfish). Sunfishes were less dominant and catfishes and redhorse suckers more dominant in the river above both reservoirs (station A), than at the tailwater stations. Fish abundance at station A was probably affected by the upstream migration of fish (gizzard shad, common carp, white crappies) from the reservoir.

123. If we assume that the biota of headwater station A is representative of an unimpounded stream environment, it is evident that the communities at station 3 in both Barren and Green tailwaters, respectively 21.1 and 22.5 km below the dams, had not recovered from the stress of project operations.

124. In summary, invertebrate and fish populations at Barren and Green tailwaters were subjected to (a) high- and low-flow water years in 1979 and 1980, respectively; (b) low water temperatures caused by low-level water releases from the dam; and (c) elevated concentrations of iron, manganese, and ammonia. Large numbers of fish and larval Diptera were exported from the reservoirs. Benthos that were intolerant to the conditions below these reservoirs were eliminated while more tolerant invertebrate species survived (and some

flourished). The macroinvertebrate communities near the dams were most affected, and those farther downstream were less affected. Surface runoff, allochthonous inputs of organic material, local climatological conditions, and changes in stream morphometry moderated the effects of the reservoir discharge downstream and resulted in the return to more natural conditions. Unstressed invertebrate communities were found above the reservoirs. The net result of flood flows, reduced temperatures, and export of reservoir fish was a tailwater fish community numerically dominated by gizzard shad, white crappies, and bluegills. Fish distribution within the tailwater was probably determined by export of fish from the reservoir and availability of habitat. Native stream fishes, including catfishes and redhorse suckers, were more abundant in the unregulated stream (station A).

Comparison of warmwater and coldwater releases

125. Water temperatures in tailwaters of flood-control projects with coldwater releases were 5 to 12°C lower in the summer than those in tailwaters with warmwater releases. Discharge rates were generally similar in all four tailwaters. Summer discharges were maintained at their established minimums during 1980, when precipitation was below normal. In 1979, however, when precipitation was greater than normal, minimum flows were sustained only in Pine Creek tailwater. Extended flood releases were required at the other three sites.

126. Water low in dissolved oxygen was withdrawn from all four reservoirs during the summers of 1979 and 1980. However, reaeration in the reservoir outlet works was sufficient to maintain dissolved oxygen levels above 5.0 mg/ℓ in all tailwaters. The anoxic water drawn from the reservoir hypolimnions contained substantial quantities of iron and manganese; these chemicals were precipitated in all tailwaters, primarily during August, September, and October. Levels of both iron and manganese were highest in Pine Creek tailwater. Slightly lower values of conductivity, alkalinity, pH, and particulate matter were recorded in the warmwater tailwaters, but these differences are

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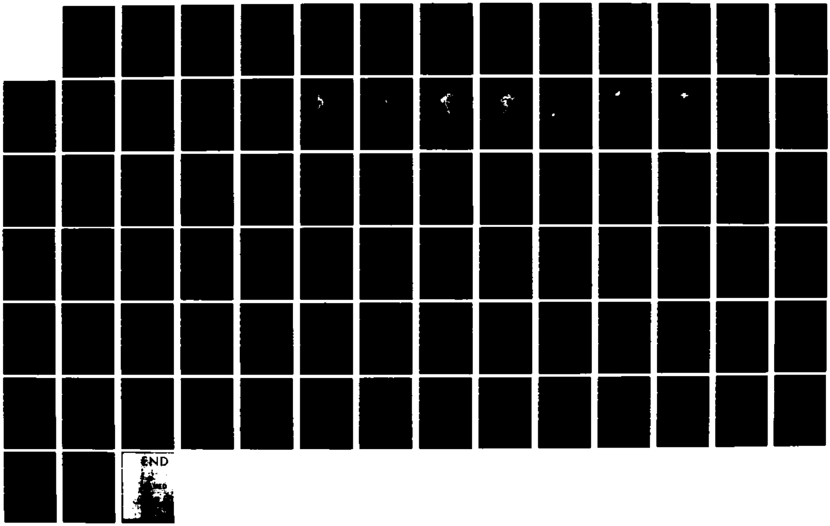

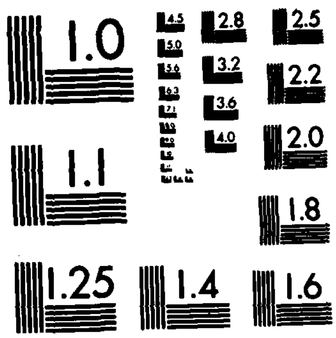

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most likely based on drainage basin differences, rather than the level of water release from the reservoir.

127. The macroinvertebrate communities in tailwaters of flood-control projects with warmwater release had greater numbers of organisms, greater biomass, and more taxa than did the communities in tailwaters of flood-control projects with coldwater release. The warm water below Pine Creek and Gillham was more conducive to production of many taxa and high numbers of organisms. Chironomidae, Trichoptera, Hydracarina, Nematoda, Oligochaeta, and Isopoda were more common in the immediate tailwaters of Pine Creek and Gillham, whereas Simuliidae and Turbellaria were more common near the dams at Barren and Green.

128. Macroinvertebrate communities in tailwaters below all four flood-control projects were least diverse near the dams and increased in diversity downstream. Invertebrate communities in riffle areas close to the dams were more susceptible to catastrophic destruction from seasonal flood releases. Lotic insects that exhibit behavioral drift (Ephemeroptera, Trichoptera, Plecoptera) probably had difficulty recolonizing this section because the reservoir replaced the lotic environment upstream and conditions in the immediate tailwatere were no longer suitable for these species (Lehmkuhl 1979). If this were the case, only a limited number of taxa, primarily more tolerant benthic invertebrates (Chironomidae, Oligochaeta, Turbellaria), would be available to recolonize denuded riffles in the immediate tailwater. Downstream, the impact of seasonal flood flows would be moderated by differences in channel morphometry and habitat, allowing members of drifting lotic taxa to survive. These survivors would provide a source for recolonizing denuded riffles and would help maintain higher downstream diversities (Herricks and Cairns 1974-76).

129. Drift samples collected from station 1 in tailwaters of all flood-control projects verify that Chaoboridae was the dominant taxon in the drift and that lotic insects were only a minor component. Farther downstream, the Chaoboridae rapidly disappeared and

Ephemeroptera, Trichoptera, and Plecoptera regained their dominant positions in both the benthic community and the drift.

130. High concentrations of iron, manganese, and ammonia may have stressed the invertebrate communities in these tailwaters, but the effects of these chemicals could not be separated from other environmental factors. Periods of chemical stress would most likely occur during late summer storms or during fall drawdown, when high volumes of anoxic hypolimnetic water are released.

131. The biomass of fish captured in the tailwaters of both warmwater (Pine Creek, Gillham) and coldwater (Barren, Green) release flood-control projects was similar; however greater numbers of fish (primarily sunfishes and black basses) were captured at the warmwater release sites. A total of 95 species were captured at the four tailwaters, of which 37 were common to both tailwater types (Appendix E). Species composition did not differ substantially between 1979 and 1980 within any of the four tailwaters.

132. Relative abundance (and biomass) of fish varied between the warmwater and coldwater tailwaters. Sunfishes, suckers, and catfishes dominated at the warmwater sites, and common carp, suckers, and sunfishes at the coldwater sites (Table 36). Channel catfish, largemouth bass, bluegills, and longear sunfish were more abundant and composed a larger portion of the fish community at Pine Creek and Gillham tailwaters than at Barren and Green. Presumably the coldwater discharge into Barren and Green tailwaters repressed the abundance of these species through disruption of their life cycles. Common carp dominated fish biomass in Barren and Green tailwaters; few were collected in Pine Creek tailwater and none in Gillham tailwater. The difference in common carp abundance among tailwaters was probably related to differences in abundance of this species in the drainages rather than to differences in water temperature. The coldwater discharge in Barren and Green tailwaters provided conditions suitable for a put-and-take rainbow trout fishery in these waters.

133. Fish were most abundant at the station nearest the dam in tailwaters of all flood-control projects except Green. Blockage of

Table 36

Percentage of Fish Caught by Electroshocker and Combined Catch Rates in Pine Creek, Gillham, Barren, and Green Tailwaters, 1979 and 1980, by Number (and Weight)

	Tailwater			
Fish Family	Pine Creek	Gillham	Barren	Green
Gars	4 (20)	1 (3)	tr* (tr)	tr (1)
Herrings	5 (5)	4 (8)	28 (7)	5 (4)
Trouts			1 (tr)	1 (1)
Carps	tr (1)		12 (62)	10 (53)
Minnows	4 (1)	8 (tr)	2 (tr)	4 (tr)
Suckers	3 (13)	10 (30)	9 (16)	16 (24)
Catfishes	3 (14)	2 (13)	1 (3)	1 (2)
Sunfishes	75 (41)	65 (44)	45 (11)	51 (13)
Others	6 (5)	10 (2)	2 (1)	12 (2)
Total	100 (100)	100 (100)	100 (100)	100 (100)
Combined catch rates fish/hr, kg/hr	226.2, 24.17	246.9, 20.57	88.1, 20.82	130.8, 22.47

*tr = Less than 0.5.

upstream migration and passage out of the reservoir probably contributed to the concentrations of fish below these dams. Although fish concentrated at Green station 1, their biomass was not as great as at the downstream stations because of a lack of instream cover. Flow regimes and water quality factors did not appear to suppress total fish abundance below the flood-control projects, but they may have altered the distribution of certain species within a tailwater.

134. White crappies and bluegills were most abundant at the station nearest the dam in all four tailwaters; most of these fish probably came from the reservoirs. Longear sunfish were more abundant at downstream stations. Spotted bass were apparently unaffected by the reservoir discharge, since they were evenly distributed among all stations within a tailwater.

135. In summary, differences in tailwater macroinvertebrate composition and fish abundance were common between flood-control projects with warmwater and coldwater releases and between upstream and downstream stations within a tailwater. Since all four flood-control projects generally had the same seasonal pattern of water release, it is reasonable to assume that many of the differences in tailwater biota between flood-control projects with warmwater and coldwater releases were related to water temperature. Numbers of invertebrates were highest in tailwaters of warmwater projects. Benthic invertebrate communities in tailwaters of all flood-control projects were dominated by Chironomidae near the dam, and the drift consisted primarily of Chaoboridae exported from the reservoir. Downstream, the invertebrate communities had partly recovered from the reservoir's influence, and organisms more common to natural streams, such as Plecoptera, Trichoptera, and Ephemeroptera, were more prominent. Sunfishes (primarily black basses) were more abundant (biomass) in the tailwaters of flood-control projects with warmwater releases and common carp in tailwaters of flood-control projects with coldwater releases. Fish in tailwaters of flood-control projects were usually more abundant at the upstream station.

Hydropower Projects

136. Levels of discharge differed among the three hydropower reservoirs. Maximum releases were about 3 times greater from Hartwell (~750 m^3/sec) than from Beaver (~250 m^3/sec) and 10 times greater than from Greeson (~75 m^3/sec). All three reservoirs were operated for peak power. Weekday releases at Hartwell and Greeson were maximum for 2 to 12 hours and minimum for the rest of the day; weekend flows were usually limited to project leakage. This weekly peaking cycle generally occurred throughout the year. Operations at Beaver reservoir were more seasonal. During summer, peaking operations occurred almost daily, extending through weekends. During other seasons, sustained minimum flows frequently lasted from 6 to 31 days.

137. Water temperatures were lowest at the upstream stations in Hartwell and Greeson tailwaters (never less than 21°C) and increased downstream. Maximum temperatures in the shorter Beaver tailwater were much lower (12.2°C) and were generally similar at all three stations. Daily temperature fluctuations of 2 to 6°C were recorded in Hartwell tailwater, and temperature changes of this magnitude may have been common below all three hydropower dams.

138. Dissolved oxygen concentrations were maintained above 5.0 mg/ℓ in Beaver and Greeson tailwaters, despite the deep reservoir withdrawal. Low dissolved oxygen (<5.0 mg/ℓ) recorded below Hartwell suggests that aquatic life in this tailwater may be periodically stressed (U. S. Environmental Protection Agency 1976).

139. Variations in conductivity, pH, alkalinity, and particulate matter were minor among tailwaters and were probably related to drainage basin differences. Iron and manganese concentrations in Hartwell and Greeson tailwaters were variable but highest levels occurred during fall months. High sulfides were recorded in Hartwell tailwater; however, it is not known if these concentrations were maintained for prolonged periods. The absence of high levels of iron and manganese in Beaver tailwater was related to the maintenance of adequate dissolved oxygen levels in the reservoir hypolimnion.

140. The macroinvertebrate community at the sampling station nearest the dam in tailwaters of all three hydropower projects generally had the fewest taxa, lowest diversity, and highest density. The dominant taxa at this station were similar in all three tailwaters and consisted primarily of Chironomidae, Oligochaeta, Nematoda, and Amphipoda; Isopoda were also important in Beaver tailwater. Chironomidae, Oligochaeta, and Nematoda, although sedentary, were able to withstand the rapid changes in water depth and velocity common to these tailwaters. Amphipoda and Isopoda are mobile and apparently migrate into more protective habitat during peaking operations.

141. The dominant taxa were similar among all three stations in both Beaver and Hartwell tailwaters. At Greeson tailwater, however, the composition of the macroinvertebrate community at station 3 differed from that near the dam. The downstream community was dominated by aquatic insect taxa (e.g., Ephemeroptera and Plecoptera) that were rarely found in the rapidly fluctuating flows near the dam. Apparently the influence of the smaller hydropower releases in Greeson tailwater did not extend as far downstream as did the larger hydropower releases at Beaver and Hartwell. The return to a more natural flow and temperature regime at station 3 allowed a greater variety of aquatic insects to colonize the community.

142. The fish population in Greeson tailwater differed from those at Beaver and Hartwell. Catch rates (by electrofishing) were higher and more species were captured at Greeson (210.0 fish/hr; 48 species) than at either Beaver (43.4 fish/hr; 30 species) or Hartwell (78.7 fish/hr; 35 species). The relative importance of fish families also differed among the tailwaters of the three hydropower projects (Table 37). Stocked trout were important in the fish catch by electroshocker at Beaver and Hartwell, and sunfishes were important at Greeson. Catfishes made up only a small part of the fish community

Table 37

Percentages of Fish Caught by Electroshocker and Combined Catch Rates in Beaver, Hartwell, and Greeson Tailwaters, 1979 and 1980, by Number (and Weight)

	Tailwater		
Fish Family	Beaver	Hartwell	Greeson*
Herrings	**	2 (3)	4 (4)
Trouts	77	13 (11)	1 (1)
Carps	6	2 (29)	10 (58)
Minnows	**	36 (2)	13 (tr†)
Suckers	8	12 (42)	8 (11)
Catfishes	tr	3 (1)	tr (1)
Sunfishes	6	28 (10)	53 (13)
Others	3	4 (2)	11 (12)
Total	100	100 (100)	100 (100)
Combined catch rates fish/hr, kg/hr	43.4	78.7, 16.43	210.0, 50.27

*Sampled only in 1979.
**Percentage unknown; see paragraph 25.
†tr = Less than 0.5.

in all three tailwaters. Sport fish catch in all three hydropower tailwaters consisted primarily of trout.*

143. Distribution of fish differed in the tailwaters of the three hydropower projects. Stocked trout generally remained in the area where they were released and were most abundant at station 1 and least abundant at station 3 in all three tailwaters. Most sunfishes showed no location preference; abundances were similar at all stations within a tailwater. Several sucker species were more common at downstream stations than immediately below the dam (golden redhorse at Greeson; silver redhorse, smallfin redhorse, and northern hog suckers at Hartwell).

144. Cold water and peaking flows in these tailwaters probably reduced suitability of the habitat for some native warmwater fishes (i.e., catfishes and black basses), but provided good habitat (water temperature <21°C) for stocked trout. The effects of cold water and peaking flows differed among the various groups of fish. Several sucker species and longear sunfish were more common downstream, where temperatures were generally increased and the effects of the fluctuating flows were decreased.

145. In summary, the primary perturbations affecting the biota in tailwaters of the hydropower projects were the periodic water level and flow fluctuations, and the generally low water temperatures. Low concentrations of dissolved oxygen and high levels of iron, manganese, and ammonia in release water may have stressed the organisms living in Hartwell and Greeson tailwaters, but the effects of these conditions could not be differentiated from those caused by flow fluctuations and temperature reduction. In Beaver tailwater, the macroinvertebrate and fish communities appeared to be stressed despite the absence of high concentrations of iron, manganese, and ammonia and the presence of high levels of dissolved oxygen. The cold, fluctuating releases near

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*Trout are a major species in the Hartwell tailwater sport catch. Personal Communication, 1981, Hugh Barwick, Southeast Reservoir Investigations, Clemson, SC.

all three dams appeared to limit both macroinvertebrate and fish fauna to organisms that were able to survive in these specialized environments. Downstream, increased numbers were noted among species associated with more natural stream communities.

Comparison of Flood-Control and Hydropower Projects

146. Flows in the tailwaters of the four flood-control projects did not fluctuate daily. Minimum flows usually occurred during the summer and extended over a number of days, dependent on watershed runoff. Discharges in the tailwaters of the hydropower projects fluctuated from minimum to maximum during weekday peaking operations. Sustained minimum flows or no flows occurred only on weekends or, if longer than 2 days, only in fall, winter, and spring. Minimum discharges were less in the tailwaters of hydropower projects than in tailwaters of the flood-control projects.

147. Water temperatures in the tailwaters were determined primarily by the depth of the reservoir, the depth and volume of release, and the water storage capacity of the reservoir. Greater daily temperature fluctuations would be expected in the summer in the tailwaters of hydropower projects than in the tailwaters of flood-control projects because of large daily flow fluctuations. Solar heating rapidly increased downstream water temperatures in Barren, Green, Hartwell, and Greeson tailwaters during summer low-flow periods. Dissolved oxygen concentrations were adequate in all the tailwaters, except occasionally at Hartwell station 1. Reaeration occurred rapidly in this tailwater as the water passed downstream.

148. High levels of iron and manganese were detected in the tailwaters of both flood-control and hydropower projects (except Beaver) and were related to the lack of oxygen in the reservoir hypolimnions. The effects of elevated iron and manganese concentrations on the macroinvertebrate and fish communities in these tailwaters were not determined for this study. However, elevated levels of

iron and manganese in water from the hypolimnion of reservoirs have been associated with fish stress and mortality (Noell and Oglesby 1977; Nix and Ingols 1981). Differences in other chemical variables in project tailwaters are probably more related to drainage basin differences than to any other factor.

149. In all seven tailwaters, macroinvertebrate diversities and numbers of taxa were generally lowest at station 1, where the effects of the reservoir releases were greatest, and increased downstream. Macroinvertebrate densities were generally highest at the station nearest the dam and lowest downstream.

150. The composition of the tailwater macrobenthic communities appeared to be dependent on both the pattern of discharge and the temperature of the water released. In the tailwaters of the hydropower projects, daily water level and temperature fluctuations and the suppression of seasonal temperature changes limited the invertebrate community to more mobile or resilient groups. Aquatic insects that required specific thermal stimuli to complete their life cycles were generally eliminated. The communities in the tailwaters of the flood-control projects contained a greater variety of insects, presumably because there was usually little change in daily water release and temperature. The greatest variety of macroinvertebrates occurred in the tailwaters of the warmwater flood-control projects, where the temperatures were similar to those in natural streams of the region.

151. Long-term stability of the tailwater macrobenthic communities was also affected by the reservoir release regimes. The release regimes in the tailwaters of the hydropower projects, although pulsing on a daily basis, were relatively uniform throughout the year. This uniform release pattern provided a relatively constant environment for the organisms able to adapt to the peaking schedule. In the tailwaters of the flood-control projects, releases were often maintained at a constant volume over extended periods. Macroinvertebrate communities adapted to constant releases were severely disrupted by rapid changes in flow.

152. Tailwaters of the flood-control projects had relatively rich fish faunas, dominated by sunfishes, whereas tailwaters of the hydropower projects (except Greeson) supported fewer species. The fish community in tailwaters of the flood-control projects consisted of reservoir fish that passed through the dam, river fish, and (where water temperature permitted) stocked trout. Tailwaters of the hydropower projects (except Greeson) were dominated by stocked trout; some reservoir and river warmwater species were apparently unable to tolerate the cold water and peaking flows which occurred below the hydropower dams.

153. Trout were most abundant at the stations nearest the dam in tailwaters below hydropower projects; warmwater species were most abundant at downstream stations. In tailwaters of the flood-control projects, fish were most abundant at the upstream stations, except where habitat was limited.

154. The Greeson tailwater fish fauna resembled the faunas in the tailwaters of the flood-control projects with coldwater releases, rather than those of the two large hydropower projects. The small size of Greeson reservoir, its low maximum discharge, and rapid warming in the tailwater during summer (27.5°C in September 1979) provided marginal trout habitat; thus, warmwater species were common.

155. Angling effort, harvest, and catch rate varied among tailwaters. In tailwaters where fishing pressure was high, catch rates were low. All tailwaters provided sport fishing, despite the occurrence of environmental extremes.

156. In summary, the tailwaters of flood-control and hydropower projects differed in flow regime, water temperature, and depth and volume of the reservoir above; these factors all influenced the tailwater invertebrate and fish communities. The tailwaters of flood-control projects had less variable flows and higher water temperatures and were associated with smaller reservoirs than the tailwaters of hydropower projects (excluding Greeson). Fish and invertebrate populations in tailwaters below flood-control projects generally had a

greater variety of taxa than those in tailwaters below hydropower projects. Warmwater tailwaters had the most diverse invertebrate and fish populations.

PART VI: CONCLUSIONS

157. The conclusions drawn from analysis of data in this report are as follows:

- a. Elevated concentrations of iron, manganese, and ammonia were recorded below the six reservoirs that released anoxic water. (Releases from Beaver Lake were always from oxygenated areas of the reservoir.) The effects of these elevated concentrations on the tailwater invertebrate and fish communities were not determined in this study.

- b. In tailwaters of the four flood-control projects, invertebrate drift at the sample station nearest the dam was dominated by Chaoboridae, a common reservoir inhabitant; other macroinvertebrates were few. Farther downstream, where tailwater conditions more closely resembled those of natural streams, the abundance of Trichoptera, Ephemeroptera, and Plecoptera increased and that of Chaoboridae decreased.

- c. At both the flood-control and hydropower projects, invertebrate diversities and numbers of taxa were generally lowest at the sample station nearest the dam where environmental stress was greatest.

- d. Numbers of benthic invertebrate species were highest in tailwaters of flood-control projects with warmwater release and lowest in tailwaters below the large hydropower projects.

- e. Trout stocked in tailwaters of hydropower and flood-control projects with coldwater release moved little and generally congregated near where they were released; most were stocked near the dams. The decrease in numbers, or absence, of trout farther downstream was largely related to the rapid summer warming of water in all tailwaters except Beaver, where the tailwater was relatively short (<6 km).

- f. In the tailwaters of flood-control projects, fish were most numerous at the station closest to the dam, provided habitat was adequate. In the tailwaters of hydropower projects, warmwater species were generally more abundant downstream. Fish distribution appeared to be related to daily changes in flow, temperature, and habitat availability.

g. Fish were most abundant in the tailwaters of the flood-control projects and the small hydropower projects and least abundant in the tailwaters of the large hydropower projects.

h. Despite the occurrence of environmental stress caused by reservoir releases, all tailwaters in this study provided sport fishing. Angler surveys on six tailwaters indicated moderate to heavy fishing pressure. Stocked trout provided the major fishery in the tailwaters of hydropower projects and a significant fishery in the tailwaters of flood-control projects with coldwater release. Sunfishes, crappies, and catfishes were most important in the tailwaters of flood-control projects with warmwater release. Fishing effort at all tailwaters was greater in 1979, a high-water year, than in 1980. Angling effort was most intense in Barren and Beaver tailwaters.

i. There was no clear relation between tailwater fish catch (electrofishing or angling) and reservoir discharge volumes.

j. Instream cover (e.g., boulders, brush piles, fallen trees, pools, and backwaters) may have a moderating influence on the adverse effects of reservoir releases on tailwater biota.

k. The distance below a dam necessary for a river to return to a natural environment (i.e., unstressed by project operation) was not determined from this study. However, it appears that downstream distance will differ for every project. Factors which determine downstream distance include time, volume, depth, and water quality of releases. Release effects can be modified by tributary inflow and by hydraulic factors within the stream such as pools, riffles, and substrate.

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APPENDIX A: LOCATIONS OF RESERVOIRS AND TAILWATER AND HEADWATER SAMPLING STATIONS

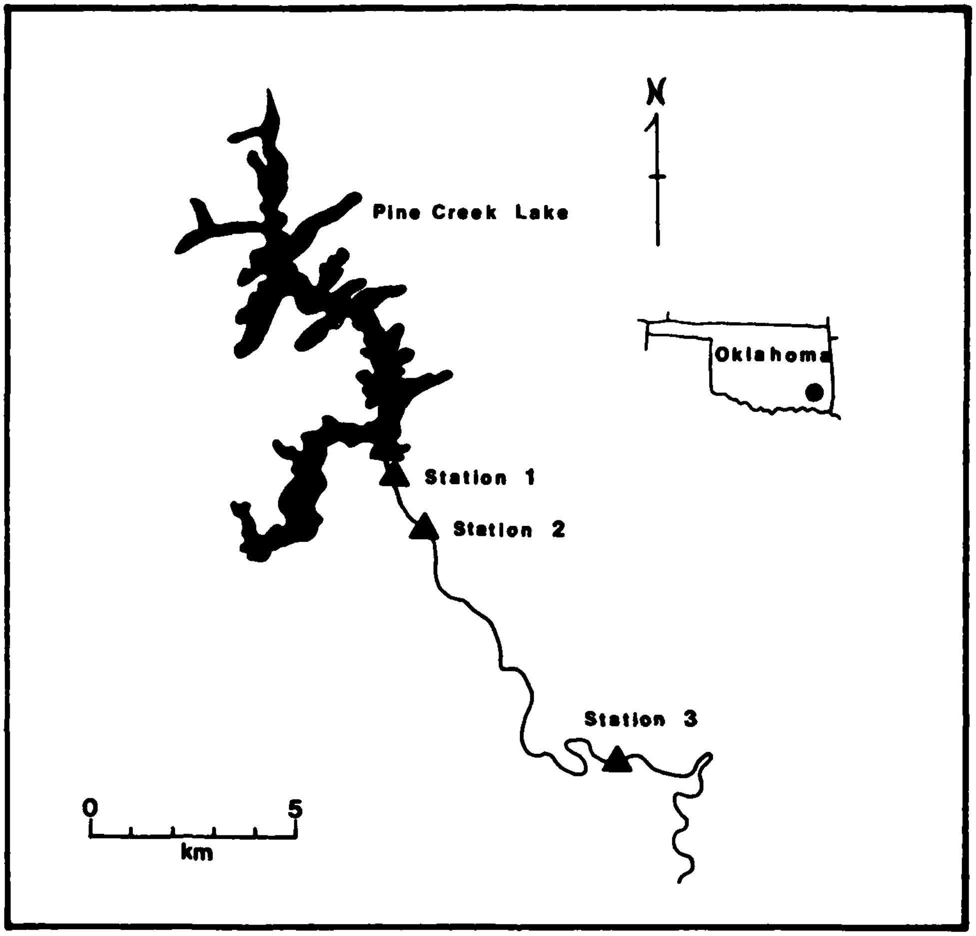

Figure A1. Pine Creek Lake and location of tailwater sampling stations

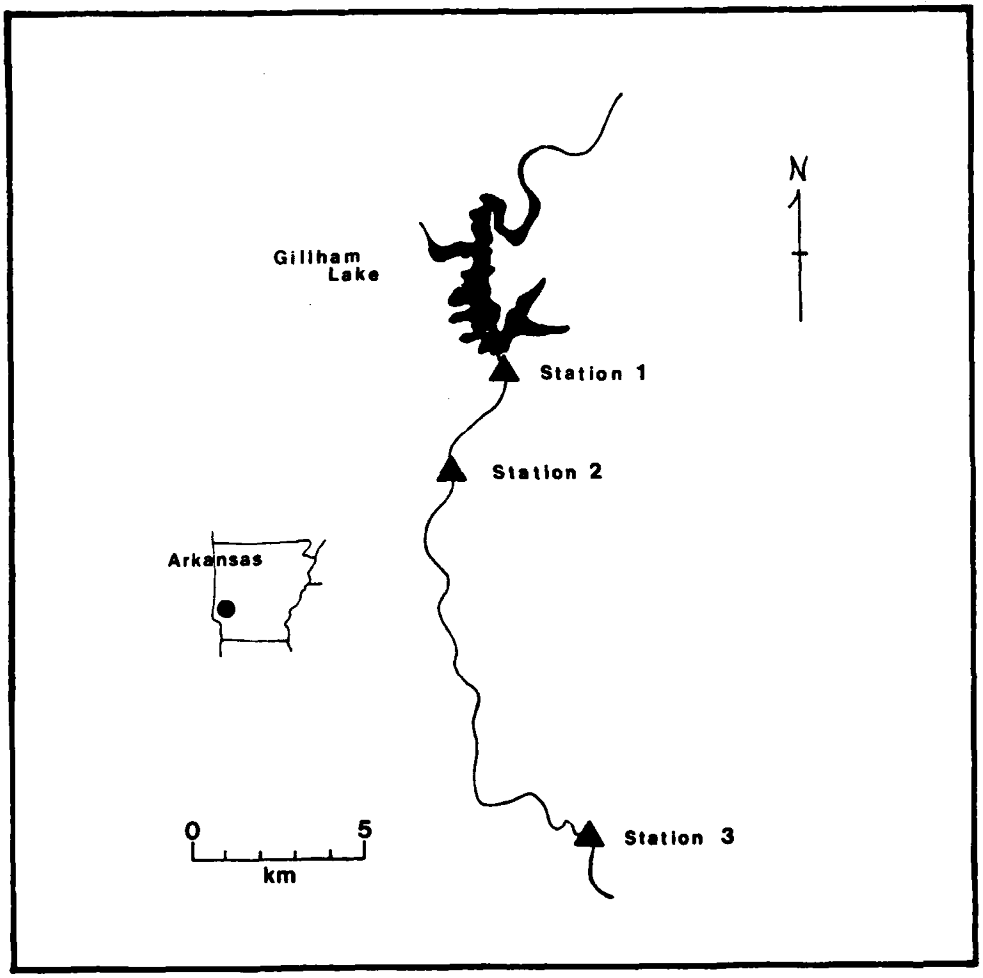

Figure A2. Gillham Lake and location of tailwater sampling stations

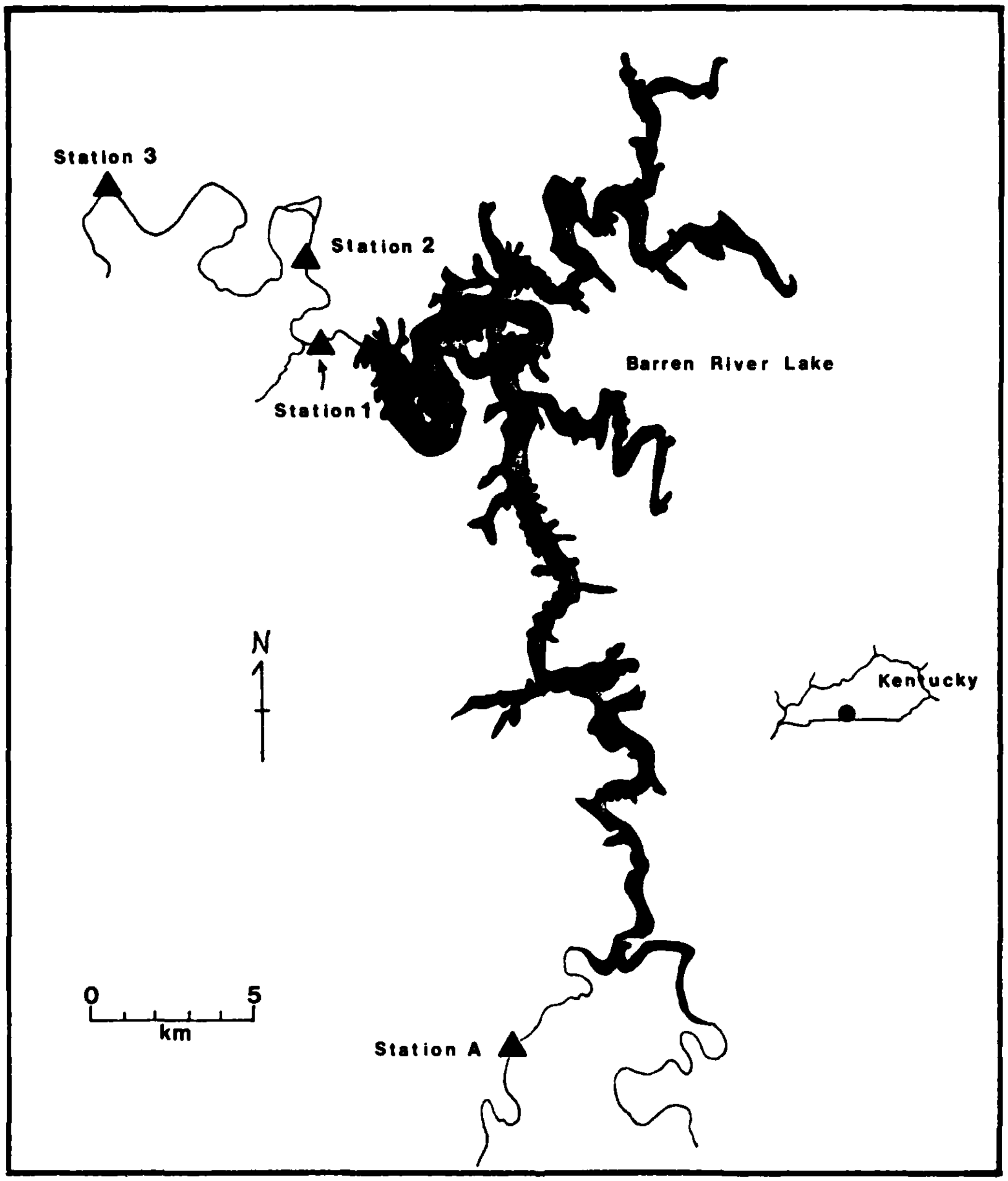

Figure A3. Barren River Lake and location of tailwater and headwater sampling stations

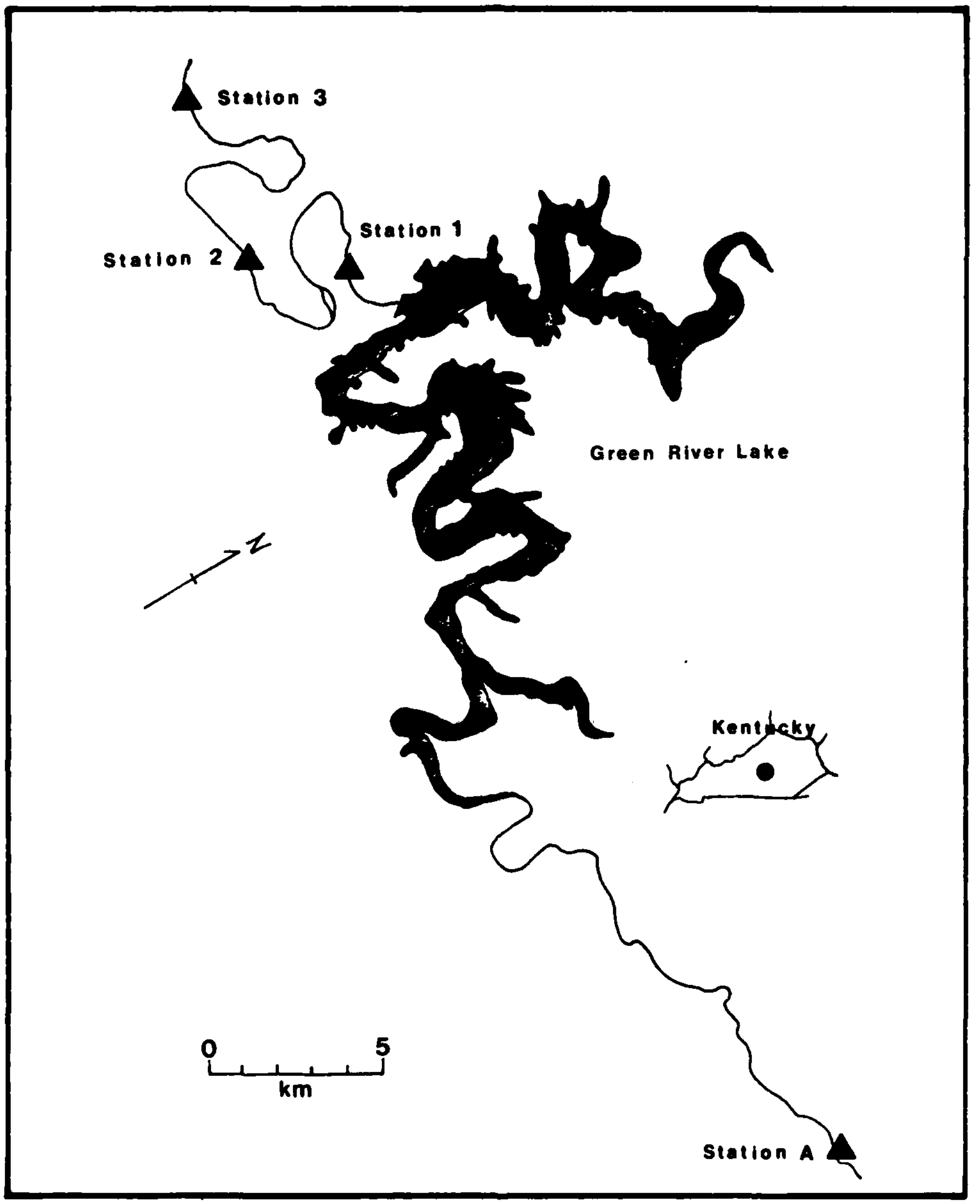

Figure A4. Green River Lake and location of tailwater and headwater sampling stations

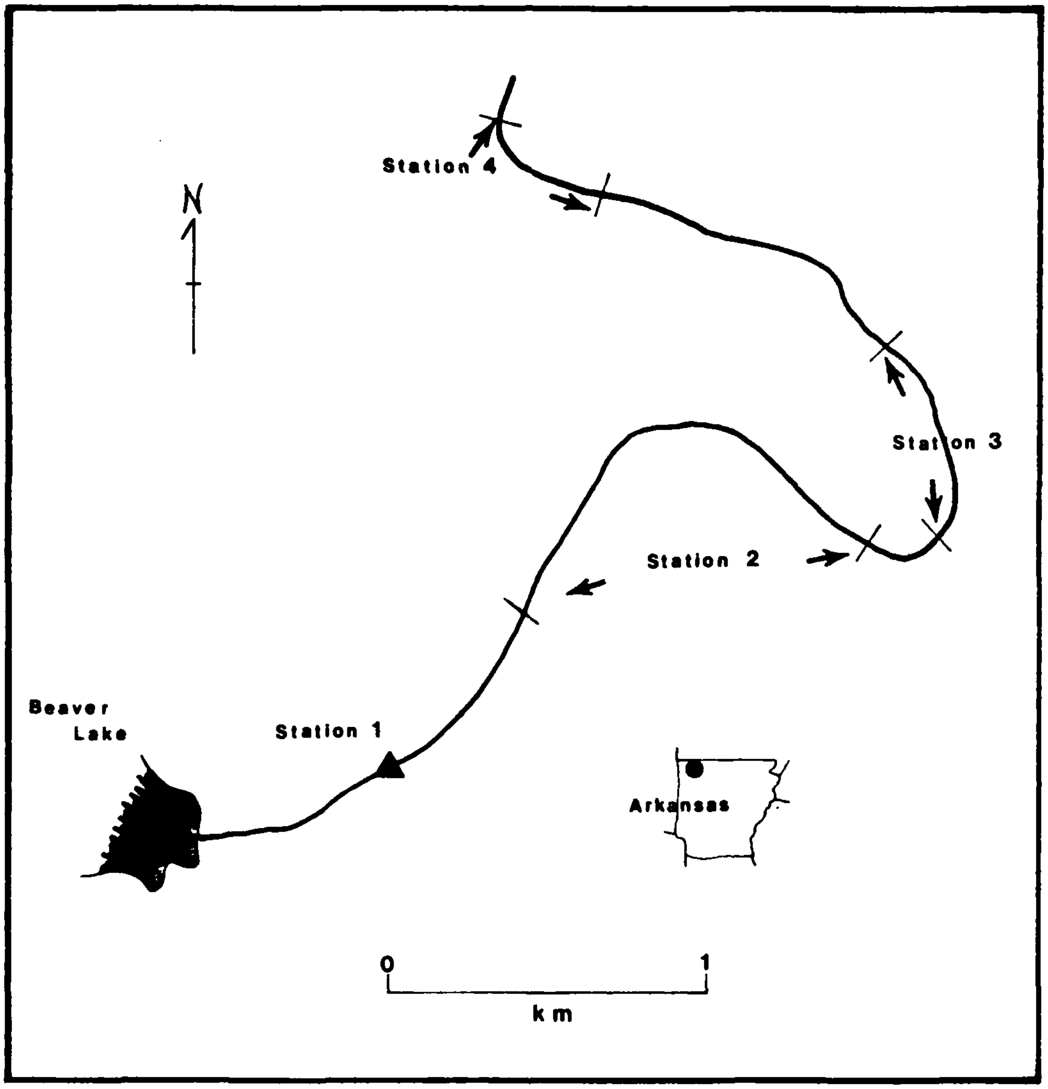

Figure A5. Location of sampling stations
in tailwater below Beaver Lake

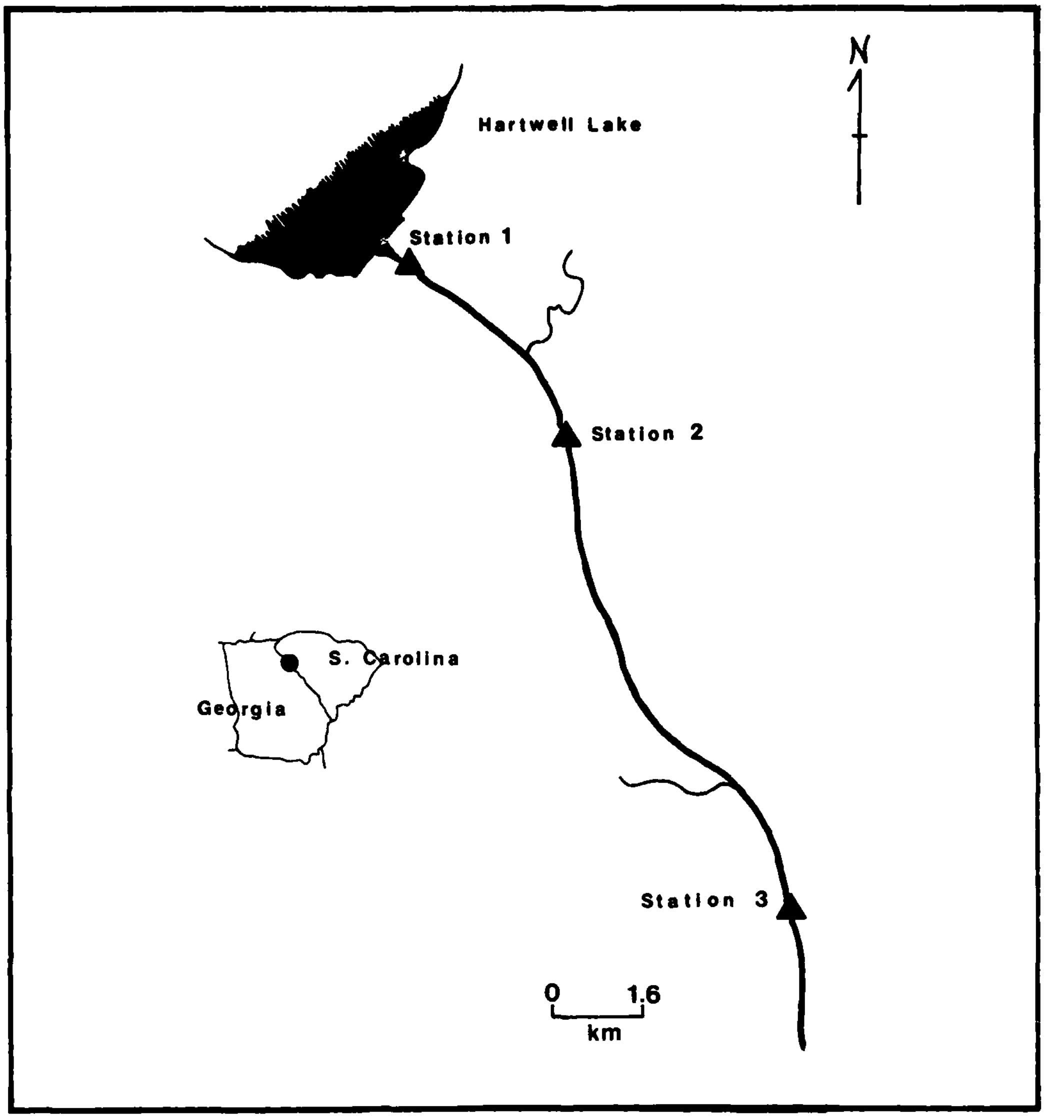

Figure A6. Hartwell Lake and location of tailwater sampling stations

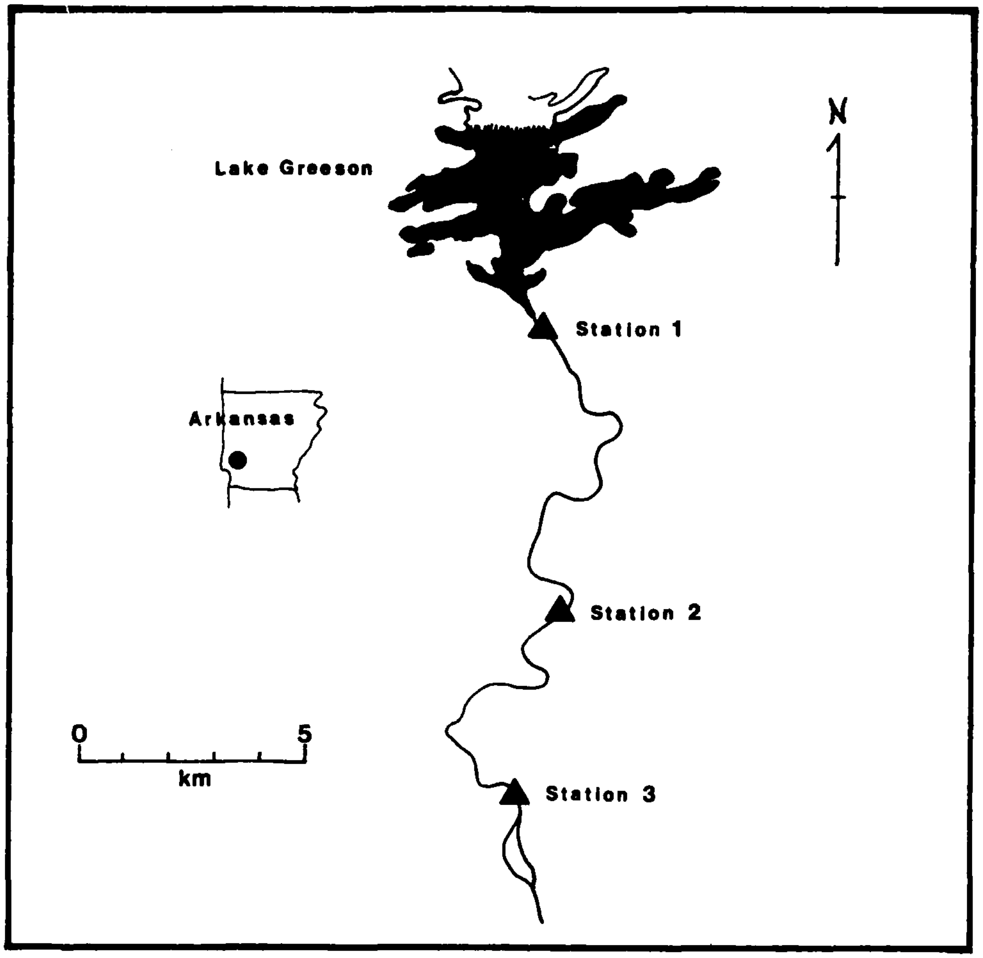

Figure A7. Lake Greeson and location of tailwater sampling stations

APPENDIX B: DESCRIPTION OF SAMPLING STATIONS AT EACH RESERVOIR AND TYPES OF SAMPLES COLLECTED

Table B1

Description of Sampling Stations in the Tailwater below Pine Creek Lake, Oklahoma, and Type of Samples Collected in 1979 and 1980*

Station	Distance Below Dam (kilometres)	Average Width x Length (metres)	Surface Area (hectares)	Average Depth, Maximum Depth (metres)	Substrate (% Composition)	Station Description	Type of Sample**
1	0.3	34 x 168	0.6	0.3 0.5	Silt 4% sand 4% gravel 20% cobble 42% boulder 30%	Shallow run with a riffle at the lower end of the station; no tree canopy or fallen timber.	W, I
2†	2.1	55 x 624	3.4	1.0 2.0	Silt 11% sand 40% gravel 17% cobble 22% boulder 10%	Wide pool with a run at upstream end and riffle at downstream end; extensive tree canopy covers both stream banks and fallen trees provide cover on the west bank.	W, I, F
3	12.1	23 x 336	0.8	1.2 1.6	Silt 14% sand 31% gravel 32% cobble 16% boulder 7%	Narrow pool with a run at upstream end and riffle at downstream end; extensive tree canopy covers the north stream bank and fallen trees provide cover on the south bank.	W, I, F

*Measurements taken at minimum established discharge (1.8 m^3/sec).
**W = water quality, I = invertebrates, F = fish.
†Invertebrates were sampled at this station in 1979 only.

Table B2

Description of Sampling Stations in the Tailwater below Gillham Lake, Arkansas, and Type of Samples Collected in 1979 and 1980*

Station	Distance Below Dam (kilometres)	Average Width x Length (metres)	Surface Area (hectares)	Average Depth, Maximum Depth (metres)	Substrate (% Composition)	Station Description	Type of Sample**
1	0.3	21 x 432	0.9	0.4 0.9	Gravel 40% cobble 55% boulder 5%	A run in a uniform channel with no tree canopy or fallen trees or large rocks for cover.	W, I
2†	4.0	46 x 244	1.1	1.7 3.2	Silt 19% sand 39% gravel 23% cobble 9% boulder 10%	Deep, wide pool with a run and gravel bar at the upstream end and a wide shallow run at the downstream end; some tree canopy, boulders and fallen trees form cover.	W, I, F
3	15.3	36 x 360	1.4	1.6 3.3	Sand 11% gravel 31% cobble 32% boulder 26%	Long pool with a run at the upstream end and a riffie at the downstream end; boulder-strewn banks provide cover and there is a large deep area in the pool.	W, I, F

*Measurements taken at minimum established discharge (0.8 m^3/sec).
**W = water quality, I = invertebrates, F = fish.
†Invertebrates were sampled at this station in 1979 only.

Table B3

Description of Sampling Stations in the Tailwater and Headwater of Barren River Lake, Kentucky, and Type of Samples Collected in 1979 and 1980*

Station	Distance Below Dam (kilometres)	Average Width x Length (metres)	Surface Area (hectares)	Average Depth, Maximum Depth (metres)	Substrate (% Composition)	Station Description	Type of Sample**
1	2.4 in 1979 1.6 in 1980	37 x 354	1.3	1.4 2.4	Silt) 30% sand) gravel 70%	Primarily a large pool with a gravel shoal (water <1.0 metre deep) located in the center of the pool; 7 percent of the surface area has fallen trees, tree roots embedded in the bank, or undercut banks.	W, I, F
2†	7.2	37 x 335	1.2	1.2 2.1	Silt 50% gravel 50%	Primarily a wide pool with one riffle and one run located at the upstream end of the station; cover is primarily fallen trees.	W, I, F
3	21.1	21 x 465	1.0	1.4 2.1	Silt 10% gravel) 73% cobble) boulder 17%	Equal amounts of pool, run, and riffle with fallen trees and large rocks providing cover; several springs flow into the station on the north bank.	W, I, F
A††	3.4 above reservoir	14 x 359	0.5	1.0 1.8	Sand 22% gravel 41% cobble) 37% boulder)	Approximately equal quantities of pool, run, and riffle were present; cover provided by overhanging vegetation, boulders, and submerged logs.	W, I, F

*Measurements taken at minimum established discharge (2.1 m^3/sec).
**W = water quality, I = invertebrates, F = fish.
†Only fish sample was taken at this station in 1980.
††Sampled only in 1980.

Table B4

Description of Sampling Stations in the Tailwater and Headwater of Green River Lake, Kentucky, and Type of Samples Collected in 1979 and 1980*

Station	Distance Below Dam (kilometres)	Average Width x Length (metres)	Surface Area (hectares)	Average Depth, Maximum Depth (metres)	Substrate (% Composition)	Station Description	Type of Sample**
1	1.5	30 x 457	1.4	0.6 1.8	Gravel 60% cobble) boulder) 40% bedrock)	Approximately 40 percent of the station is shallow run (<0.5 metres deep) with several riffles; few pools are present, cover is provided by large rocks and boulders.	W, I, F
2†	10.5	46 x 457	2.1	1.2 2.1	Gravel 80% boulder) 20% bedrock)	Most of the station is a long pool with a riffle at the downstream end; many fallen logs provide cover.	W, I, F
3	22.5	32 x 610	2.0	0.9 1.8	Silt 10% gravel 70% cobble) 20% boulder)	Diverse habitat with equal amounts of pool, riffle, and run with fallen trees, roots embedded in the banks, and large rocks providing cover.	W, I, F
A††	19.0 above reservoir	25 x 351	0.9	0.8 1.1	Silt 5% gravel 30% cobble 25% boulder) 40% bedrock)	Two large pools with one large run in the center of the station; cover was provided by logs, overhanging trees and brush, and a few small boulders.	W, I, F

*Measurements taken at minimum established discharge (2.4 m^3/sec).
**W = water quality, I = invertebrates, F = fish.
†Sampled only in 1979.
††Sampled only in 1980.

Table B5

Description of Sampling Stations in the Tailwater below Beaver Lake, Arkansas, and Type of Samples Collected in 1979 and 1980*

Station	Distance Below Dam (kilometres)	Average Width x Length (metres)	Surface Area (hectares)	Average Depth, Maximum Depth (metres)	Substrate (% Composition)	Station Description	Type of Sample**
1	0.7			0.4 1.0	Sand 3% gravel 88% cobble 9%	Riffle.	I
2	2.2	44 x 1800	7.9	1.5 3.0	Sand 4% gravel 87% cobble 9%	Large pool with about 20 percent of the area deeper than 2.0 metres. Boulders strewn below limestone bluffs and some bedrock at upper end of station.	W, I, F
3†	3.6	26 x 800	2.1	2.0 5.0		Approximately 30 percent of the pool is deeper than 2.0 metres; some boulders provide cover.	W, F
4	5.5	48 x 500	2.4	1.5 4.0	Sand 5% gravel 88% cobble 7%	Approximately 20 percent of pool deeper than 2.0 metres with cover provided by submerged logs; some bedrock present.	W, I, F

*Measurements taken at minimum flow (0.8 m^3/sec).
**W = water quality, I = invertebrates, F = fish.
†Fish were sampled at this station in 1979 only.

Table B6

Description of Sampling Stations in the Tailwater below Hartwell Lake, Georgia and South Carolina, and Type of Samples Collected in 1979 and 1980*

Station	Distance Below Dam (kilometres)	Average Width x Length (metres)	Surface Area (hectares)	Average Depth, Maximum Depth (metres)	Substrate (% Composition)	Station Description	Type of Sample**
1	1.0	61 x 392	2.4	0.9 3.3	Gravel 18% cobble 6% boulder 76%	Long shallow pool with large rocks, boulders, and a few fallen trees. Sparse vegetation, mostly blue-green or filamentous algae.	W, I, F
2	4.0	68 x 382	2.6	0.7 1.1	Sand 12% gravel 27% cobble 7% boulder 54%	Long shallow pool with large rocks, boulders, and a few fallen trees. Sparse vegetation, mostly blue-green or filamentous algae but some *Fontinalis* sp. present.	W, I, F
3	12.1	62 x 481	3.0	0.7 1.8	Sand 23% gravel 25% boulder 52%	Long shallow pool with large rocks, boulders, and a few fallen trees. Sparse vegetation, mostly blue-green algae and *Podostemum* sp.	W, I, F

*Measurements taken at minimum flow (3.0 m^3/sec).
**W = water quality, I = invertebrates, F = fish.

Table B7

Description of Sampling Stations in the Tailwater below Lake Greeson, Arkansas, and Type of Samples Collected in 1979*

Station	Distance Below Dam (kilometres)	Average Width x Length (metres)	Surface Area (hectares)	Average Depth, Maximum Depth (metres)	Substrate (% Composition)	Station Description	Type of Sample**
1	0.5	31 x 183	0.6	1.1 2.8	Silt 4% sand 31% gravel 30% cobble 22% boulder 13%	Upstream end of pool has shallow run with bedrock bottom and downstream end deeper with boulders for cover; no fallen timber in water but there is an extensive streambank tree canopy.	W, I, F
2	10.5	34 x 336	1.1	1.7 4.0	Silt 3% sand 16% gravel 8% cobble 17% boulder 56%	Long relatively deep pool with a run upstream and a riffle downstream; extensive tree canopy on both stream-banks with fallen timber and boulders for cover.	W, I, F
3	16.1	31 x 549	1.7	1.5 3.3	Silt 73% sand 15% gravel 8% cobble 4%	Long pool of which only the upstream half was sampled and the upstream boundry was a riffle; extensive tree canopy on streambanks; some fallen timber for cover.	W, I, F

*Measurements taken at minimum flow (0.3 m^3/sec).
**W = water quality, I = invertebrates, F = fish.

APPENDIX C: METHODS AND EQUIPMENT USED TO DETERMINE CHEMICAL AND PHYSICAL VARIABLES AT EACH RESERVOIR, 1979 AND 1980

Table C1

Pine Creek Lake, Gillham Lake, and Lake Greeson

Variable	Analytical Method	Instrumentation*	Preservation Technique
Alkalinity	Potentiometric titration	Digi-sense pH meter	Cool to 4°C
Ammonia	Specific ion electrode	Orion Model 901	Acidify to pH <2
Conductivity	Electrometric	Yellow Springs Instrument Model 33	In situ
Total iron	Atomic absorption spectrophotometry	Perkin-Elmer Model 303	Acidify to pH <2
Total manganese	Atomic absorption spectrophotometry	Perkin-Elmer Model 303	Acidify to pH <2
Oxygen, dissolved	Winkler titration (1979) Membrane electrode (1980)	Yellow Springs Instrument Model 57	In situ
pH	Electrometric (1979) Colormetric (1980)	Digi-sense pH meter Hellige or Hach color comparators	On site
Sulfides	Odor, if detected Titrimetric (iodine) method		On site
Temperature	Thermistor thermometer Mercury thermometer	Yellow Springs Instrument Model 33	In situ
Particulate matter	Filtration and ignition (10 litres)		Cool to 4°C

*Reference to trade names does not imply endorsement of commercial products by the United States Fish and Wildlife Service.

Table C2

Barren River Lake and Green River Lake

Variable	Analytical Method	Instrumentation	Preservation Technique
Alkalinity	Potentiometric titration	Coleman Model 38 pH meter (1979) Hach Digital pH meter Model 18800-10 (1980)	Cool to 4°C
Ammonia	Selective ion electrode	Orion Model 407A (1979) Orion Model 901 (1980)	Acidify to pH <2
Conductivity	Electrometric	Hach Model 2510 conductivity meter (1979) Hydrolab Surveyor Model 6D (1980)	In situ
Total iron	Atomic absorption spectrophotometry	Perkin-Elmer Model 303	Acidify to pH <2
Total manganese	Atomic absorption spectrophotometry	Perkin-Elmer Model 303	Acidify to pH <2
Oxygen, dissolved	Winkler titration (1979) Membrane electrode (1980)	Hydrolab Surveyor Model 6D	In situ
pH	Electrometric	Coleman Model 38 pH meter (1979) Hach Digital pH meter Model 18800-10 (1980)	Cool to 4°C
Sulfides	Odor, if detected Titrimetric (iodine) method		On site
Temperature	Mercury thermometer (1979 and 1980) Thermistor thermometer (1980)	Hydrolab Surveyor Model 6D	In situ
Particulate matter	Filtration and ignition (10 litres)		Cool to 4°C

Table C3

Beaver Lake

Variable	Analytical Method	Instrumentation	Preservation Technique
Alkalinity	Potentiometric titration	Orion Model 701 (1979) Hach Digital Titrator (1980)	Cool to 4°C On site
Ammonia	Specific ion electrode	Orion Model 701	Chloroform
Conductivity	Electrometric	Hydrolab Conductivity Meter (1979) Hach DR-EL/4 (1980)	In situ On site
Total iron	Atomic absorption spectrophotometry	Perkin-Elmer Model 303	Acidify to pH <2
Total manganese	Atomic absorption spectrophotometry	Perkin-Elmer Model 303	Acidify to pH <2
Oxygen, dissolved	Membrane electrode (1979) Winkler titration (1980)	Yellow Springs Instrument Model 54	In situ On site
pH	Electrometric	Orion Model 701 (1979) Hach DR-EL/4 (1980)	Cool to 4°C On site
Sulfides	Odor, if detected Titrimetric (iodine) method		On site
Temperature	Thermistor thermometer (1979) Mercury thermometer (1980)	Yellow Springs Instrument Model 54	In situ
Particulate matter	Filtration and ignition (30 litres)		Cool to 4°C

Table C4

Hartwell Lake

Variable	Analytical Method	Instrumentation	Preservation Technique
Alkalinity	Potentiometric titration	Orion Model 407A	Cool to 4°C
Ammonia	Selective ion electrode	Orion Model 407A	Cool to 4°C
Conductivity	Electrometric	Hydrolab System 8000	In situ
Total iron	Plasma emission spectrography	Jarrell-Ash Plasma Atomcomp Model 750	Acidify to pH <2
Total manganese	Plasma emission spectrography	Jarrell-Ash Plasma Atomcomp Model 750	Acidify to pH <2
Oxygen, dissolved	Membrane electrode	Hydrolab System 8000	In situ
pH	Electrometric	Hydrolab System 8000	In situ
Sulfides	Titrimetric (iodine) method		Cool to 4°C
Temperature	Thermistor thermometer	Hydrolab System 8000	In situ
Particulate matter	Filtration and ignition (20 litres)		Cool to 4°C

APPENDIX D: FISH CATCH RATES BY STATION AND YEAR IN SIX OF THE SEVEN STUDY TAILWATERS, 1979 AND 1980

Table D1

Fish Catch per Hour by Electroshocker at Stations 2 and 3 in the Tailwaters below Pine Creek Lake, 1979

Species	Station 2 No./hr	Station 2 kg/hr	Station 3 No./hr	Station 3 kg/hr	Stations Combined No./hr	Stations Combined kg/hr
Chestnut lamprey	1.7	0.03	0.7	0.01	1.2	0.02
Spotted gar	14.0	6.97	2.6	0.78	8.6	4.04
Longnose gar	0.7	1.43			0.4	0.75
Bowfin	0.3	0.75			0.2	0.40
Gizzard shad	9.7	1.36	10.4	1.31	10.0	1.34
Emerald shiner			0.4	tr*	0.2	tr
Pugnose minnow	0.7	tr	0.7	tr	0.7	tr
Blacktail shiner			2.6	0.01	1.2	tr
Mimic shiner			0.4	tr	0.2	tr
Steelcolor shiner	4.7	0.02	8.2	0.05	6.3	0.03
Bluntnose minnow	0.7	tr	2.6	0.01	1.6	0.01
Spotted sucker	4.3	1.59	0.4	0.10	2.5	0.88
River redhorse			1.5	1.49	0.7	0.70
Black redhorse	0.3	0.07	0.4	0.10	0.4	0.08
Golden redhorse	1.3	0.61	7.1	2.82	4.0	1.65
Yellow bullhead	0.3	0.14			0.2	0.08
Channel catfish	10.0	4.29	4.8	3.24	7.6	3.79
Freckled madtom			0.7	tr	0.4	tr
Flathead catfish	0.3	1.00			0.2	0.53
Blackspotted topminnow	1.0	tr	0.4	tr	0.2	tr
Brook silverside	2.7	tr			1.4	tr
Yellow bass	1.3	0.06			0.7	0.03
Green sunfish	3.3	0.12	6.3	0.39	4.7	0.25
Warmouth	4.0	0.15	2.6	0.10	3.3	0.13
Bluegill	75.3	2.59	35.3	1.24	56.4	1.95
Longear sunfish	49.3	1.04	73.2	1.50	60.6	1.26
Redear sunfish	5.3	0.31	1.5	0.06	3.5	0.20
Spotted sunfish			0.4	tr	0.2	tr
Spotted bass	11.3	1.39	10.0	0.84	10.7	1.13
Largemouth bass	7.3	2.49	7.1	2.14	7.2	2.32
White crappie	22.0	2.29			11.6	1.20
Black crappie	10.3	1.19	8.2	1.05	9.3	1.12
Greenside darter	0.3	tr			0.2	tr
Logperch	3.7	0.05	1.9	0.03	2.8	0.04
Dusky darter	0.3	tr			0.2	tr
Freshwater drum	1.0	1.19	1.1	1.06	1.1	1.13
Total	247.4	31.13	191.5	18.33	220.7	25.06
Number of species	30		27		36	
Hours fished	3.00		2.69		5.69	

*tr = Less than 0.005.

Table D2

Fish Catch per Hour by Electroshocker at Stations 2 and 3 in the Tailwaters below Pine Creek Lake, 1980

Species	Stations 2 No./hr	Stations 2 kg/hr	Stations 3 No./hr	Stations 3 kg/hr	Stations Combined No./hr	Stations Combined kg/hr
Chestnut lamprey			0.4	tr*	0.2	tr
Southern brook lamprey			0.4	tr	0.2	tr
Spotted gar	10.0	5.82	3.1	1.46	6.7	3.72
Longnose gar	0.4	2.08	0.4	0.01	0.4	1.08
Bowfin	0.8	0.74			0.4	0.38
Gizzard shad	17.1	0.75	12.5	1.89	14.9	1.30
Common carp	0.4	1.14			0.2	0.59
Emerald shiner			0.4	tr	0.2	tr
Pugnose minnow			0.4	tr	0.2	tr
Redfin shiner			3.1	tr	1.5	tr
Blacktail shiner			3.1	0.01	1.5	0.01
Steelcolor shiner	3.7	0.02	8.5	0.05	6.0	0.03
Bigmouth buffalo	0.8	1.04			0.4	0.54
Spotted sucker	2.9	0.82	0.9	0.01	1.9	0.43
River redhorse	0.4	0.50			0.2	0.26
Black redhorse			0.9	0.05	0.4	0.03
Golden redhorse	4.2	1.92	2.2	1.53	3.2	1.73
Channel catfish	2.9	3.69	2.2	0.95	2.6	2.37
Flathead catfish	0.8	0.09			0.4	0.05
Blackspotted topminnow	2.9	0.01	6.3	0.01	4.5	0.01
Brook silverside	0.8	tr	13.0	0.01	6.7	0.01
Yellow bass	0.4	0.01			0.2	0.01
Green sunfish	5.8	0.25	18.3	0.43	11.9	0.34
Warmouth	5.4	0.23	2.7	0.13	4.1	0.18
Bluegill	103.1	4.03	39.8	1.29	72.6	2.71
Longear sunfish	21.2	0.59	75.2	1.50	47.2	1.03
Redear sunfish	4.6	0.32	1.8	0.20	3.2	0.26
Spotted bass	9.1	1.60	10.3	1.32	9.7	1.47
Largemouth bass	11.6	4.71	4.5	0.48	8.2	2.67
White crappie	23.7	2.27	0.9	0.05	12.7	1.20
Black crappie	6.7	0.66	1.8	0.20	4.3	0.43
Logperch	3.3	0.04	3.1	0.04	3.2	0.04
Channel darter			0.4	tr	0.2	tr
Slenderhead darter			0.4	tr	0.2	tr
Freshwater drum			0.4	0.46	0.2	0.22
Total	243.0	33.33	217.4	12.08	230.6	23.10
Number of species	25		29		35	
Hours fished	2.39		2.24		4.63	

*tr = Less than 0.005.

Table D3

Fish Catch per Hour by Electroshocker at Stations 2 and 3 in the Tailwaters below Gillham Lake, 1979

Species	Stations 2 No./hr	Stations 2 kg/hr	Stations 3 No./hr	Stations 3 kg/hr	Stations Combined No./hr	Stations Combined kg/hr
Spotted gar	1.7	0.79	0.9	0.41	1.1	0.49
Bowfin			0.5	1.02	0.4	0.80
Gizzard shad	32.0	4.00	9.5	1.21	14.3	1.80
Central stoneroller	1.7	tr*	3.2	tr	2.9	tr
Ribbon shiner	1.7	tr	0.5	tr	0.7	tr
Redfin shiner			10.4	0.02	8.2	0.02
Steelcolor shiner			1.8	0.02	1.4	0.01
Bluntnose minnow	5.1	0.01	3.2	tr	3.6	tr
Spotted sucker	1.7	0.13	1.8	0.16	1.8	0.16
River redhorse			1.8	2.47	1.4	1.95
Black redhorse	28.6	4.86	3.2	0.53	8.6	1.45
Golden redhorse	13.5	3.56	15.8	3.73	15.3	3.70
Yellow bullhead			0.5	0.03	0.4	0.03
Channel catfish	8.4	3.52	2.3	1.62	3.6	2.02
Flathead catfish	3.4	1.77	0.5	0.02	1.1	0.39
Pirate perch			0.5	tr	0.4	tr
Northern studfish			0.5	tr	0.4	tr
Blackspotted topminnow	6.7	0.01	9.0	0.01	8.6	0.01
Brook silverside	3.4	0.01	8.6	0.01	7.5	0.01
White bass	1.7	0.72			0.4	0.15
Yellow bass			6.8	0.18	5.3	0.14
Rock bass			0.5	0.09	0.4	0.07
Green sunfish	16.8	1.13	21.2	1.25	20.3	1.23
Warmouth	1.7	0.01	0.9	0.04	1.1	0.04
Bluegill	60.6	0.97	23.5	0.34	31.4	0.48
Longear sunfish	60.6	1.10	102.1	1.60	93.3	1.49
Redear sunfish	1.7	0.11	3.2	0.25	2.9	0.22
Spotted sunfish			0.5	tr	0.4	tr
Smallmouth bass	1.7	0.32	2.7	0.87	2.5	0.75
Spotted bass	5.1	0.14	18.5	2.16	15.7	1.74
Largemouth bass	25.3	13.51	4.5	1.47	8.9	4.01
White crappie	11.8	0.67	0.5	0.02	2.9	0.16
Black crappie	3.4	0.31	1.8	0.23	2.1	0.25
Orangebelly darter			0.5	tr	0.4	tr
Logperch	1.7	0.02	3.6	0.03	3.2	0.03
Channel darter			1.8	tr	1.4	tr
Blackside darter			0.9	tr	0.7	tr
Leopard darter	1.7	0.01			0.4	tr
Dusky darter			3.2	0.01	2.5	0.01
Total	301.7	37.68	271.2	19.80	277.9	23.61
Number of species	25		37		39	
Hours fished	0.59		2.21		2.80	

*tr = Less than 0.005.

Table D4

Fish Catch per Hour by Electroshocker at Stations 2 and 3 in the Tailwaters below Gillham Lake, 1980

Species	Station 2 No./hr	Station 2 kg/hr	Station 3 No./hr	Station 3 kg/hr	Stations Combined No./hr	Stations Combined kg/hr
Lamprey species	1.9	0.01	0.3	tr*	0.9	tr
Chestnut lamprey	1.3	0.01	2.1	0.02	1.8	0.02
Southern brook lamprey	2.5	0.01	1.7	0.01	2.0	0.01
Spotted gar	0.6	0.03	1.0	0.47	0.9	0.31
Longnose gar	1.3	0.20	1.0	0.32	1.1	0.28
Gizzard shad	7.5	1.18	7.3	1.69	7.4	1.51
Chain pickerel			0.3	tr	0.2	tr
Central stoneroller	0.6	tr	2.1	0.01	1.6	0.01
Bigeye shiner			0.7	tr	0.4	tr
Redfin shiner	6.2	0.01	10.1	0.02	8.7	0.02
Steelcolor shiner	1.9	0.02	8.0	0.04	5.8	0.03
Bluntnose minnow	8.8	tr	2.1	0.01	4.5	0.01
Spotted sucker	1.3	0.25	0.3	0.08	0.7	0.14
River redhorse	0.6	0.60	0.3	0.44	0.4	0.50
Black redhorse	17.5	3.34	3.8	0.76	8.7	1.68
Golden redhorse	17.5	4.17	8.7	2.69	11.9	3.22
Yellow bullhead			0.3	tr	0.2	tr
Channel catfish	1.9	0.66	3.1	2.04	2.7	1.55
Freckled madtom			2.1	0.01	1.3	tr
Flathead catfish	1.3	0.30	1.7	1.72	1.6	1.21
Blackspotted topminnow	8.8	0.01	4.2	0.01	5.8	0.01
Brook silverside			2.8	0.01	1.8	tr
Striped bass			0.3	0.16	0.2	0.10
Green sunfish	22.6	0.84	22.0	1.07	22.2	0.98
Warmouth	3.8	0.20	0.7	0.09	1.8	0.13
Bluegill	63.3	1.52	28.9	0.57	41.2	0.91
Longear sunfish	50.7	0.96	64.5	1.61	59.6	1.38
Redear sunfish	3.8	0.24	2.8	0.17	3.1	0.20
Smallmouth bass	0.6	tr			0.2	tr
Spotted bass	5.6	0.89	14.3	1.56	11.2	1.32
Largemouth bass	15.0	7.41	4.2	0.61	8.1	3.04
White crappie	1.3	0.07	0.7	0.05	0.9	0.06
Black crappie	0.6	tr	0.3	0.07	0.4	0.05
Creole darter			0.3	tr	0.2	tr
Harlequin darter			0.3	tr	0.2	tr
Orangebelly darter			2.4	tr	1.6	tr
Orangethroat darter			0.7	tr	0.4	tr
Speckled darter	0.6	tr			0.2	tr
Logperch	2.5	0.03	3.5	0.03	3.1	0.03
Channel darter	1.3	tr	2.4	tr	2.0	tr
Dusky darter	1.3	tr	0.7	tr	0.9	tr
Total	254.5	22.96	213.0	16.34	227.9	18.71
Number of species	31		39		41	
Hours fished	1.60		2.87		4.47	

*tr = Less than 0.005.

Table D5

Fish Catch per Hour by Electroshocker at Stations 1, 2, and 3 in the Tailwaters below Barren River Lake, 1979

Species	Stations 1 No./hr	Stations 1 kg/hr	Stations 2 No./hr	Stations 2 kg/hr	Stations 3 No./hr	Stations 3 kg/hr	Stations Combined No./hr	Stations Combined kg/hr
Longnose gar	0.1	0.08			0.2	0.06	0.1	0.04
American eel	0.1	0.01	0.2	0.13			0.1	0.06
Gizzard shad	7.1	0.84	3.2	0.57	1.9	0.19	3.9	0.53
Rainbow trout	0.4	0.05	0.2	0.02			0.2	0.02
Central stoneroller			0.1	tr*			tr	tr
Common carp	8.8	10.99	7.5	7.62	8.9	10.19	8.3	9.40
Emerald shiner	0.9	0.01					0.3	tr
Spotfin shiner					2.2	0.02	0.7	0.01
Steelcolor shiner	0.2	tr					0.1	tr
Northern hog sucker	0.1	0.02	1.1	0.27	0.6	0.18	0.7	0.17
Spotted sucker	4.2	1.23	5.3	1.38	0.3	0.18	3.5	0.96
River redhorse			0.4	0.44	0.6	0.79	0.4	0.42
Black redhorse	2.0	0.89	1.5	0.52	0.9	0.34	1.5	0.57
Golden redhorse	0.2	0.13	0.4	0.22			0.2	0.13
Shorthead redhorse			0.1	0.06	0.9	0.56	0.3	0.20
Channel catfish	0.8	0.30	0.5	0.11	0.4	0.17	0.6	0.18
Flathead catfish	0.2	0.24					0.1	0.07
Brook silverside					0.1	tr	tr	tr

*tr = Number less than 0.05; weight less than 0.005.

(Continued)

Table D5 (Concluded)

Species	Stations 1		Stations 2		Stations 3		Stations Combined	
	No./hr	kg/hr	No./hr	kg/hr	No./hr	kg/hr	No./hr	kg/hr
Rock bass	0.5	0.05	1.4	0.17	0.2	0.01	0.8	0.09
Warmouth	1.9	0.10	0.8	0.03	1.4	0.05	1.3	0.06
Hybrid sunfish	0.1	0.02	0.1	tr			0.1	0.01
Bluegill	7.4	0.33	10.8	0.45	2.7	0.09	7.3	0.30
Longear sunfish	21.4	0.85	29.4	1.02	4.0	0.22	19.2	0.72
Redear sunfish					0.1	tr	tr	tr
Smallmouth bass			0.1	0.01	0.1	tr	0.1	0.01
Spotted bass	4.5	0.55	4.3	0.54	3.5	0.45	4.1	0.52
Largemouth bass	0.4	0.33	0.8	0.91			0.4	0.46
White crappie	9.6	0.21	2.6	0.02	1.1	0.03	4.2	0.08
Black crappie	2.1	0.15	0.8	0.06	0.4	0.03	1.1	0.08
Banded darter			0.1	tr			tr	tr
Logperch	0.2	0.01	0.6	0.01	0.1	tr	0.3	0.01
Slenderhead darter			0.1	tr			tr	tr
Dusky darter					0.1	tr	tr	tr
Freshwater drum	0.4	0.28			0.1	0.09	0.1	0.11
Banded sculpin					0.1	tr	tr	tr
Total	73.6	17.67	72.4	14.56	30.9	13.65	60.0	15.21
Number of species	24		25		24		35	
Hours fished	8.51		11.79		9.24		29.54	

Table D6

Fish Catch per Hour by Electroshocker at Stations 1, 2, and 3 in the Tailwaters below Barren River Lake and at Station A in Long Creek, a Tributary above the Reservoir, 1980

Species	Stations 1* No./hr	Stations 1* kg/hr	Stations 2 No./hr	Stations 2 kg/hr	Stations 3 No./hr	Stations 3 kg/hr	Tailwater Stations Combined No./hr	Tailwater Stations Combined kg/hr	Station A No./hr	Station A kg/hr
Longnose gar	0.2	0.15			0.4	0.12	0.3	0.12		
American eel	0.2	0.12			0.1	0.06	0.1	0.08		
Gizzard shad	114.9	5.27	9.6	0.48	3.4	0.50	50.2	2.47	19.9	1.85
Rainbow trout	1.8	0.28	0.8	0.09			0.8	0.12		
Grass pickerel									0.5	0.03
Central stoneroller	0.1	tr**	1.2	0.02	0.2	tr	0.3	tr	0.4	0.01
Goldfish	0.1	0.07			0.2	tr	0.1	0.03		
Common carp	16.1	23.00	4.0	2.94	12.6	15.19	13.1	17.10	7.2	10.19
Common shiner									1.1	0.08
Spottail shiner					0.1	tr	tr	tr		
Silver shiner									1.5	0.01
Rosyface shiner	0.1	tr			0.2	tr	0.1	tr	0.4	tr
Spotfin shiner	0.3	tr			1.3	0.01	0.8	tr	0.8	0.01
Suckermouth minnow					0.1	tr	tr	tr		
Bluntnose minnow	0.5	tr			1.3	tr	0.9	tr	1.0	tr
Fathead minnow	0.1	0.01			0.1	tr	0.1	tr	0.1	tr
River carpsucker	0.9	0.96					0.4	0.40		
Northern hog sucker	0.2	tr	0.8	0.20	1.0	0.14	0.6	0.09	3.8	0.60
Smallmouth buffalo					0.1	0.10	tr	0.05		
Spotted sucker	6.9	2.06	16.0	2.79	1.2	0.26	5.1	1.28	2.1	0.37
Redhorse species			0.4	tr			tr	tr	0.1	0.10
River redhorse	0.6	0.53			1.0	1.57	0.7	0.97	0.4	0.41
Black redhorse	1.7	0.98	1.2	0.78	1.1	0.71	1.3	0.83	12.7	2.79
Golden redhorse	0.5	0.23	1.2	0.95	0.7	0.53	0.7	0.45	4.4	1.22
Shorthead redhorse					0.6	0.41	0.3	0.19		

*Station 1 moved from 2.6 km below dam in 1979 to 1.6 km in 1980.
**tr = Number less than 0.05; weight less than 0.005.

(Continued)

Table D6 (Concluded)

Species	Stations 1 No./hr	Stations 1 kg/hr	Stations 2 No./hr	Stations 2 kg/hr	Stations 3 No./hr	Stations 3 kg/hr	Tailwater Stations Combined No./hr	Tailwater Stations Combined kg/hr	Station A No./hr	Station A kg/hr
Catfish species	0.1	0.01					tr	tr		
Yellow bullhead									0.1	0.02
Channel catfish	2.4	2.24	0.4	0.06	0.2	0.03	1.1	0.95	5.1	1.79
Flathead catfish	0.2	0.88					0.1	0.37		
Spring cavefish					0.1	tr	tr	tr		
Brook silverside	3.1	0.01			0.2	tr	1.4	tr	0.1	tr
White bass	2.0	0.77			0.1	0.02	0.9	0.33	0.6	0.13
White bass x striped bass hybrid					0.1	tr	tr	tr		
Rock bass	0.4	0.07	0.4	tr	1.4	0.13	0.9	0.09	1.1	0.09
Green sunfish	0.8	0.02	0.4	tr	0.4	0.01	0.6	0.01	1.9	0.07
Warmouth	0.7	0.04	0.8	0.03	2.9	0.12	1.8	0.08	0.3	0.01
Bluegill	13.5	0.49	4.0	0.15	5.8	0.24	8.8	0.33	1.5	0.07
Longear sunfish	19.7	0.66	46.7	1.53	5.2	0.21	15.6	0.54	18.7	0.57
Redear sunfish	0.2	0.01					0.1	tr		
Smallmouth bass			0.4	tr	0.6	0.05	0.3	0.02		
Spotted bass	5.9	0.79	6.0	0.23	5.5	0.37	5.7	0.53	4.1	0.45
Largemouth bass	0.9	0.59	0.8	0.14	0.1	0.02	0.5	0.27	0.6	0.14
White crappie	9.3	0.10	0.8	0.03	4.7	0.10	6.2	0.09	0.2	0.03
Black crappie	2.2	0.13	0.4	0.04	1.2	0.10	1.5	0.11	0.1	0.02
Darter species			0.4	tr			tr	tr		
Greenside darter									0.2	tr
Rainbow darter	0.2	tr			0.1	tr	0.1	tr	0.3	tr
Fantail darter			0.4	tr			tr	tr		
Orangethroat darter					0.1	tr	tr	tr		
Banded darter					0.2	tr	0.1	tr		
Logperch	0.5	0.01	0.4	tr	0.6	0.01	0.6	0.01	0.9	0.01
Slenderhead darter					0.2	tr	0.1	tr		
Dusky darter	0.1	tr			0.4	tr	0.3	tr		
Freshwater drum	0.5	0.12					0.2	0.05		
Banded sculpin			0.8	tr	0.7	0.01	0.4	tr	0.3	0.01
Total	207.9	40.60	98.3	10.46	56.5	21.02	123.2	27.96	92.5	21.08
Number of species	36		24		41		50		33	
Hours fished	9.69		2.51		11.24		23.44		10.80	

Table D7

Fish Catch per Hour by Electroshocker at Stations 1, 2, and 3 in the Tailwaters below Green River Lake, 1979

Species	Stations 1 No./hr	Stations 1 kg/hr	Stations 2 No./hr	Stations 2 kg/hr	Stations 3 No./hr	Stations 3 kg/hr	Stations Combined No./hr	Stations Combined kg/hr
Ohio lamprey	0.1	tr*					tr	tr
American brook lamprey					0.1	tr	tr	tr
Longnose gar			0.4	0.06	0.6	0.31	0.3	0.12
American eel			0.2	0.15	0.1	0.19	0.1	0.12
Gizzard shad	18.1	2.49	1.1	0.14	3.8	0.56	7.4	1.02
Mooneye					0.4	0.06	0.1	0.02
Rainbow trout	3.6	0.58					1.1	0.18
Muskellunge					0.1	0.01	tr	tr
Central stoneroller	0.5	tr	0.1	tr	0.7	tr	0.4	tr
Common carp	4.8	6.52	17.3	14.55	19.6	19.12	14.0	13.45
Bigeye chub					0.4	tr	0.1	tr
Streamline chub					0.1	tr	tr	tr
Golden shiner	0.1	tr					tr	tr
Rosefin shiner					0.1	tr	tr	tr
Common shiner	0.2	0.01	0.5	0.02	0.8	0.02	0.5	0.02
Silver shiner					0.2	tr	0.1	tr
Spotfin shiner			0.7	tr	2.4	0.02	1.0	0.01
Bluntnose minnow	0.9	0.01	4.8	0.01	6.2	0.01	4.0	0.01
Creek chub					0.1	tr	tr	tr
Northern hog sucker	3.3	0.62	1.7	0.27	10.2	1.41	4.9	0.75
Spotted sucker	0.4	0.09	2.6	0.70	0.1	0.02	1.1	0.29
Silver redhorse			0.3	0.19			0.1	0.07
Redhorse species	5.1	1.75	0.8	0.02			1.9	0.56
River redhorse					0.2	0.14	0.1	0.04
Black redhorse	10.4	2.95	2.4	0.67	7.1	2.36	6.4	1.94
Golden redhorse	0.1	0.03	1.5	0.60	3.8	1.22	1.8	0.62
Shorthead redhorse	1.0	0.35	0.2	0.04	4.4	1.23	1.8	0.52
Channel catfish	0.3	0.06	1.1	0.44	0.2	0.03	0.5	0.19
Flathead catfish			0.1	0.06			tr	0.02

*tr = Number less than 0.05; weight less than 0.005.

(Continued)

Table D7 (Concluded)

Species	Stations 1 No./hr	1 kg/hr	2 No./hr	2 kg/hr	3 No./hr	3 kg/hr	Stations Combined No./hr	Stations Combined kg/hr
Northern studfish					0.3	tr	0.1	tr
Brook silverside	0.1	tr					tr	tr
White bass	0.8	0.05			0.1	0.04	0.3	0.03
Rock bass	5.1	0.83	4.8	0.42	6.3	0.60	5.4	0.61
Green sunfish	0.1	tr	0.1	0.01			0.1	tr
Warmouth			0.2	tr	0.3	0.01	0.2	tr
Bluegill	2.6	0.10	1.3	0.04	2.5	0.07	2.1	0.07
Longear sunfish	7.9	0.34	29.7	0.89	36.9	1.48	25.1	0.90
Smallmouth bass	4.2	0.18	0.3	tr	0.6	0.15	1.6	0.11
Spotted bass	2.0	0.08	2.6	0.14	2.6	0.18	2.4	0.14
Largemouth bass			0.3	0.16	1.1	0.20	0.5	0.12
White crappie	64.8	2.06	16.1	0.84	3.9	0.21	27.8	1.03
Orangefin darter					0.2	tr	0.1	tr
Greenside darter	5.4	0.03	0.1	tr	0.4	tr	1.9	0.01
Rainbow darter	3.9	0.01	0.3	tr	0.5	tr	1.5	tr
Fantail darter			0.1	tr	0.1	tr	0.1	tr
Stripetail darter					0.1	tr	tr	tr
Speckled darter					0.3	tr	0.1	tr
Banded darter					0.1	tr	tr	tr
Logperch	3.9	0.05	2.5	0.03	0.6	0.01	2.3	0.03
Channel darter	0.4	tr	0.2	tr	0.3	tr	0.3	tr
Gilt darter	0.1	tr	0.1	tr	0.4	tr	0.2	tr
Blackside darter					0.1	tr	tr	tr
Slenderhead darter			0.5	tr			0.2	tr
Dusky darter					0.1	tr	tr	tr
Sauger	0.1	0.04					tr	0.01
Walleye					0.2	0.22	0.1	0.07
Freshwater drum			0.1	0.08	0.2	0.12	0.1	0.07
Banded sculpin	0.7	0.01			0.1	tr	0.2	tr
Total	151.0	19.24	95.1	20.53	120.0	30.00	120.4	23.15
Number of species	31		34		48		58	
Hours fished	10.58		11.97		10.64		33.19	

Table D8

Fish Catch per Hour by Electroshocker at Stations 1 and 3 in the Tailwaters below Green River Lake and at Station A in the River above the Reservoir, 1980

Species	Stations 1 No./hr	Stations 1 kg/hr	Stations 3 No./hr	Stations 3 kg/hr	Tailwater Stations Combined No./hr	Tailwater Stations Combined kg/hr	Station A No./hr	Station A kg/hr
Longnose gar	0.4	0.14	1.6	0.34	1.0	0.24		
American eel			0.2	0.12	0.1	0.06		
Gizzard shad	1.6	0.11	3.0	0.60	2.3	0.36	60.1	3.01
Rainbow trout	4.1	0.62			2.1	0.31		
Grass pickerel							1.1	0.05
Central stoneroller	8.4	0.10	6.4	0.03	7.4	0.07	0.7	0.01
Common carp	4.7	4.15	12.6	11.08	8.7	7.62	16.2	18.16
Streamline chub			0.4	0.01	0.2	tr*		
Gravel chub			1.2	0.01	0.6	tr		
Common shiner	0.7	0.03	0.7	0.02	0.7	0.02	0.7	0.03
Spottail shiner			0.4	tr	0.2	tr		
Silver shiner	1.4	0.01			0.7	tr		
Rosyface shiner			0.7	tr	0.4	tr	0.2	tr
Spotfin shiner	1.1	tr	1.2	0.01	1.2	tr		
Suckermouth minnow			2.5	0.01	1.2	0.01	0.5	tr
Bluntnose minnow	3.2	0.01	22.8	0.04	13.0	0.03	0.7	tr
White sucker	0.4	0.11			0.2	0.06		
Northern hog sucker	8.4	1.17	15.0	1.77	11.7	1.47	7.5	0.91
Spotted sucker	0.9	0.21	6.9	0.14	3.9	0.18	7.1	0.07
Silver redhorse			0.2	0.23	0.1	0.12	0.7	0.18
River redhorse			0.2	0.11	0.1	0.05		
Black redhorse	7.9	2.93	10.5	3.62	9.2	3.28	37.3	4.96
Golden redhorse	0.2	0.04	7.8	3.35	4.0	1.70	14.9	2.98
Shorthead redhorse	0.2	0.08	3.2	0.95	1.7	0.51	3.9	0.94
Yellow bullhead							0.2	0.04
Channel catfish	0.7	0.43	1.4	0.54	1.1	0.49	9.1	2.06
Flathead catfish	0.5	0.74	0.4	0.33	0.4	0.53	0.5	4.05

*tr = Less than 0.005.

(Continued)

Table D8 (Concluded)

Species	Stations 1 No./hr	Stations 1 kg/hr	Stations 3 No./hr	Stations 3 kg/hr	Tailwater Stations Combined No./hr	Tailwater Stations Combined kg/hr	Station A No./hr	Station A kg/hr
Northern studfish			0.2	tr	0.1	tr		
Brook silverside							0.9	tr
White bass	0.2	0.11			0.1	0.06	1.4	0.52
Rock bass	6.3	0.85	4.5	0.44	5.4	0.64	0.5	0.05
Green sunfish	1.8	0.05			0.9	0.02	1.4	0.06
Warmouth			1.2	0.07	0.6	0.04	2.3	0.08
Bluegill	3.2	0.17	1.2	0.05	2.2	0.11	5.0	0.19
Longear sunfish	11.3	0.47	55.6	1.44	33.5	0.95	23.1	0.59
Smallmouth bass	10.9	0.25	0.7	0.07	5.8	0.16	0.2	0.19
Spotted bass	5.2	0.11	3.0	0.14	4.1	0.13	6.4	0.79
White crappie	36.1	1.80	3.4	0.24	19.7	1.02	8.2	0.49
Orangefin darter			0.4	tr	0.2	tr		
Greenside darter	7.2	0.04	0.7	tr	3.9	0.02		
Rainbow darter	7.2	0.01	1.2	tr	4.2	0.01		
Fantail darter			0.2	tr	0.1	tr		
Johnny darter			0.2	tr	0.1	tr		
Speckled darter			0.4	tr	0.2	tr		
Banded darter	0.4	tr	0.5	tr	0.4	tr		
Logperch	7.2	0.13	2.7	0.04	4.9	0.09	1.4	0.01
Channel darter	1.3	tr	0.2	tr	0.7	tr		
Gilt darter			0.2	tr	0.1	tr		
Slenderhead darter			0.5	tr	0.3	tr		
Dusky darter			0.4	tr	0.2	tr	0.2	tr
Sauger	0.4	0.25			0.2	0.12		
Freshwater drum	0.2	0.10			0.1	0.05		
Banded sculpin	1.1	0.03			0.5	0.01		
Total	144.8	15.25	176.7	25.80	160.7	20.54	212.4	40.42
Number of species	33		42		50		29	
Hours fished	5.59		5.62		11.21		4.37	

Table D9

Number of Fish Captured per Hour by Electroshocker at Stations 2, 3, and 4 in the Tailwaters below Beaver Lake, 1979

Species	Stations - No./hr 2	3	4	Stations Combined
Longnose gar		0.1		tr*
Gizzard shad	**	0.9	6.4	**
Rainbow trout	46.1	24.5	7.7	30.6
Largescale stoneroller		**		**
Common carp	1.0	1.1	0.2	0.9
Common shiner	0.1			tr
Ozark minnow		**		**
Steelcolor shiner	0.1			tr
Northern hog sucker			1.7	0.3
Black redhorse	0.5			0.2
Golden redhorse	3.7	0.7	3.2	2.4
Green sunfish	0.6	0.2		0.3
Bluegill	0.7	0.1	1.7	0.6
Longear sunfish			0.4	tr
Spotted bass	0.1		0.9	0.2
White crappie	0.1			tr
Black crappie	0.2			0.1
Logperch	**	**	**	**
Mottled sculpin	**	**	**	**
Total	53.2	27.6	22.2	35.6
Number of species	14	11	10	19
Hours fished	11.42	11.42	4.67	27.51

*tr = Less than 0.05.
**Species observed but not collected.

Table D10

Number of Fish Captured per Hour by Electroshocker at Stations 2 and 4 in the Tailwaters below Beaver Lake, 1980

Species	Stations - No./hr 2	4	Stations Combined
Longnose gar		0.6	0.2
Gizzard shad	**	**	**
Rainbow trout	54.1	6.9	37.3
Largescale stoneroller	**	**	**
Common carp	3.0	8.5	5.0
Common shiner	**	**	**
Ozark minnow	**	**	**
Quillback		3.2	1.1
White sucker	0.1	0.2	0.2
Northern hog sucker	0.1	2.2	0.8
River redhorse		0.1	tr*
Black redhorse		0.1	tr
Golden redhorse	1.8	3.8	2.5
Channel catfish		0.1	tr
Brook silverside	**	**	**
White bass		**	**
Green sunfish	1.0		0.7
Bluegill	1.0	2.6	1.6
Longear sunfish	0.2	0.2	0.2
Redear sunfish		0.1	tr
Spotted bass		2.1	0.7
Largemouth bass	0.7	1.0	0.8
White crappie	0.3		0.2
Black crappie	0.3	0.6	0.4
Walleye		0.4	0.1
Logperch	**	**	**
Darter species		2.2	0.8
Mottled sculpin	**	**	**
Banded sculpin	0.1		tr
Total	62.7	34.9	52.6
Number of species	19	26	29
Hours fished	14.79	8.16	22.95

*tr = Less than 0.05.
**Species observed but not collected.

Table D11

Fish Catch per Hour by Electroshocker at Stations 1, 2, and 3 in the Tailwaters below Hartwell Lake, 1979

Species	Station 1 No./hr	Station 1 kg/hr	Station 2 No./hr	Station 2 kg/hr	Station 3 No./hr	Station 3 kg/hr	Stations Combined No./hr	Stations Combined kg/hr
Gizzard shad	0.2	0.06	4.7	1.31	2.2	0.60	2.2	0.62
Threadfin shad	0.2	tr*					0.1	tr
Rainbow trout	16.4	2.17	5.4	0.87	0.9	0.22	7.5	1.08
Brown trout	9.9	1.82	3.1	0.90	0.5	0.31	4.5	1.00
Chain pickerel	0.3	0.09	0.1	0.02			0.2	0.04
Common carp	0.3	0.81	3.1	8.45	2.4	6.11	1.9	4.97
Bluehead chub	0.2	0.02			0.1	tr	0.1	0.01
Golden shiner			0.1	tr			tr	tr
Spottail shiner	4.1	0.05	24.1	0.31	14.9	0.23	13.8	0.19
Whitefin shiner	1.1	tr	0.4	tr			0.5	tr
Quillback					0.2	0.22	0.1	0.07
Creek chubsucker	0.6	0.05	0.8	0.06	0.1	0.01	0.5	0.04
Northern hog sucker	0.1	0.06	2.8	0.65	2.3	0.57	1.7	0.42
Spotted sucker	1.0	0.53	0.7	0.69	1.4	1.38	1.1	0.89
Silver redhorse	0.1	0.01	5.9	7.31	8.8	8.28	5.0	5.16
Smallfin redhorse			1.7	1.19	4.6	2.71	2.2	1.34

*tr = Number less than 0.05; weight less than 0.005.

(Continued)

Table D11 (Concluded)

Species	Station 1 No./hr	Station 1 kg/hr	Station 2 No./hr	Station 2 kg/hr	Station 3 No./hr	Station 3 kg/hr	Stations Combined No./hr	Stations Combined kg/hr
Snail bullhead			1.0	0.08	0.1	0.01	0.3	0.03
White catfish			0.4	0.08	0.4	0.06	0.3	0.05
Brown bullhead	0.2	0.02	3.5	0.36	1.0	0.17	1.5	0.17
Flat bullhead			0.1	0.01			tr	tr
White bass	0.1	0.02	0.7	0.13	0.1	0.03	0.3	0.06
White bass x striped bass hybrid					0.1	0.01	tr	tr
Striped bass					0.1	0.01	tr	0.01
Sunfish species					0.1	tr	tr	tr
Redbreast sunfish	8.0	0.50	15.7	0.85	6.7	0.65	9.7	0.66
Green sunfish	3.1	0.14	5.4	0.07	3.4	0.12	3.9	0.11
Pumpkinseed	0.1	tr					tr	tr
Warmouth			0.4	0.03	0.4	0.01	0.3	0.01
Bluegill	3.3	0.23	2.0	0.12	6.0	0.43	3.9	0.27
Redear sunfish	0.1	0.03					tr	0.01
Spotted sunfish					0.2	tr	0.1	tr
Largemouth bass	0.7	0.17	0.3	0.07	2.0	1.08	1.0	0.47
Yellow perch	0.3	tr	1.2	0.12	5.7	0.68	2.6	0.29
Blackbanded darter			0.1	tr	0.2	tr	0.1	tr
Walleye	0.1	0.08					tr	0.02
Total	50.5	6.86	83.7	23.68	64.9	23.90	65.4	17.99
Number of species	23		25		27		35	
Hours fished	9.09		7.64		9.74		26.47	

Table D12

Fish Catch per Hour by Electroshocker at Stations 1, 2, and 3 in the Tailwaters below Hartwell Lake, 1980

Species	Stations 1		Stations 2		Stations 3		Stations Combined	
	No./hr	kg/hr	No./hr	kg/hr	No./hr	kg/hr	No./hr	kg/hr
Gizzard shad			0.6	0.13	0.8	0.20	0.5	0.12
Rainbow trout	9.8	1.22	7.4	0.82	0.2	0.06	5.3	0.65
Brown trout	4.7	0.67	2.6	0.68	0.3	0.25	2.4	0.51
Chain pickerel	0.4	0.19					0.1	0.06
Common carp	0.2	0.35	2.8	7.64	1.8	4.71	1.6	4.29
Bluehead chub	0.4	0.03			0.6	0.04	0.4	0.02
Spottail shiner	19.9	0.22	105.9	1.39	29.0	0.40	50.2	0.65
Whitefin shiner	1.4	0.01	1.0	tr*	0.2	tr	0.8	tr
Quillback			0.2	0.43	0.3	0.27	0.2	0.23
Creek chubsucker	0.8	0.07			0.2	tr	0.3	0.02
Northern hog sucker			3.2	1.13	3.2	0.73	2.2	0.63
Spotted sucker	0.6	0.34	0.2	0.06	1.0	1.18	0.6	0.58
Silver redhorse			3.2	3.53	6.2	5.39	3.4	3.17
Smallfin redhorse	0.2	0.05			2.9	1.19	1.2	0.47
Snail bullhead			0.6	0.03	0.3	0.01	0.3	0.01
White catfish	0.4	0.01	0.4	0.03			0.2	0.01
Brown bullhead	0.6	0.08	3.0	0.39	0.6	0.07	1.4	0.17
Flat bullhead			0.2	0.02	0.2	0.01	0.1	0.01

*tr = Less than 0.005.

(Continued)

Table D12 (Concluded)

Species	Stations 1 No./hr	Stations 1 kg/hr	Stations 2 No./hr	Stations 2 kg/hr	Stations 3 No./hr	Stations 3 kg/hr	Stations Combined No./hr	Stations Combined kg/hr
White bass			0.2	0.09			0.1	0.03
White bass x striped bass hybrid			0.4	0.11	0.2	0.19	0.2	0.11
Sunfish species	0.2	0.01			0.3	0.02	0.2	0.01
Redbreast sunfish	14.6	0.84	11.2	0.73	12.3	1.01	12.7	0.87
Green sunfish	3.9	0.17	8.0	0.15	7.6	0.25	6.6	0.19
Warmouth	0.6	0.02	0.2	tr	0.2	0.01	0.3	0.01
Bluegill	7.1	0.38	2.0	0.15	6.5	0.40	5.3	0.32
Spotted sunfish			0.6	tr			0.2	tr
Largemouth bass	2.0	0.85	0.6	0.04	0.5	0.18	1.0	0.34
Yellow perch	0.8	0.09	1.8	0.13	3.2	0.59	2.0	0.29
Blackbanded darter	0.2	tr	1.0	tr	1.5	0.01	0.9	tr
Walleye			0.2	0.26			0.1	0.08
Total	68.8	5.60	157.5	17.94	80.1	17.17	100.8	13.85
Number of species	20		25		25		30	
Hours fished	4.92		5.02		6.17		16.11	

APPENDIX E: COMMON AND SCIENTIFIC NAMES OF FISHES MENTIONED IN THE TEXT AND THEIR RELATIVE ABUNDANCE IN CATCHES BY ELECTROFISHING IN EACH OF THE SEVEN STUDY TAILWATERS

Table E1

Names and Relative Abundance of Fishes Collected by Electroshocking in Seven Tailwaters, 1979 and 1980

Common name	Scientific name	Tailwaters* Pine Creek	Gillham	Barren	Green	Beaver	Hartwell	Greeson
Lampreys								
Ohio lamprey	*Ichthyomyzon bdellium*				I**			
Chestnut lamprey	*I. castaneus*	I	C					I
Southern brook lamprey	*I. gagei*	I	C					I
American brook lamprey	*Lampetra appendix*				I			
Gars								
Spotted gar	*Lepisosteus oculatus*	C	C					C
Longnose gar	*L. osseus*	I	I	I	I	I		I
Bowfins								
Bowfin	*Amia calva*	I	I					C
Freshwater eels								
American eel	*Anguilla rostrata*			I	I			I
Herrings								
Gizzard shad	*Dorosoma cepedianum*	A	A	A	C	A	C	C
Threadfin shad	*D. petenense*						I	
Mooneyes								
Mooneye	*Hiodon tergisus*				I			

*Entries are defined as follows: A = abundant species, ≥10 fish/hour
C = common species, ≥1 and <10 fish/hour
I = infrequently collected, <1 fish/hour

**Actual species abundance in each tailwater could differ from that observed because of between species difference in catchability by electroshocker

(Continued)

(Sheet 1 of 6)

Table E1 (Continued)

Common name	Scientific name	Tailwaters						
		Pine Creek	Gillham	Barren	Green	Beaver	Hartwell	Greeson
Trouts								
Rainbow trout	_Salmo gairdneri_			I	C	A	C	C
Brown trout	_S. trutta_						C	
Pikes								
Grass pickerel	_Esox americanus vermiculatus_							I
Muskellunge	_E. masquinongy_				I			
Chain pickerel	_E. niger_		I				I	C
Carps and minnows								
Central stoneroller	_Campostoma anomalum_		C	I	C			
Largescale stoneroller	_C. oligolepis_					A		
Goldfish	_Carassius auratus_			I				
Common carp	_Cyprinus carpio_	I		A	A	C	C	A
Bigeye chub	_Hybopsis amblops_		I		I			
Streamline chub	_H. dissimilis_				I			
Gravel chub	_H. x-punctata_				I			
Bluehead chub	_Nocomis leptocephalus_						I	
Golden shiner	_Notemigonus crysoleucas_				I		I	
Rosefin shiner	_Notropis ardens_				I			
Emerald shiner	_N. atherinoides_	I		I				I
Bigeye shiner	_N. boops_							C
Common shiner	_N. cornutus_				I	A		
Pugnose minnow	_N. emiliae_	I						
Ribbon shiner	_N. fumeus_		I					
Spottail shiner	_N. hudsonius_			I	I		A	
Whitefin shiner	_N. niveus_						I	
Ozark minnow	_N. nubilus_					A		
Kiamichi shiner	_N. ortenburgeri_							C
Silver shiner	_N. photogenis_				I			
Rosyface shiner	_N. rubellus_			I	I			
Spotfin shiner	_N. spilopterus_			I	C			

(Continued)

(Sheet 2 of 6)

Table E1 (Continued)

Common name	Scientific name	Tailwaters: Pine Creek	Gillham	Barren	Green	Beaver	Hartwell	Greeson
Carps and minnows cont.								
Redfin shiner	N. umbratilis	I	C					C
Blacktail shiner	N. venustus	C						
Mimic shiner	N. volucellus	I						
Steelcolor shiner	N. whipplei	C	C	I		I		
Suckermouth minnow	Phenacobius mirabilis			I	I			
Bluntnose minnow	Pimephales notatus	I	C	I	C			A
Fathead minnow	P. promelas			I				
Creek chub	Semotilus atromaculatus				I			
Suckers								
River carpsucker	Carpiodes carpio			I				
Quillback	C. cyprinus					I	I	
White sucker	Catostomus commersoni				I	I		
Creek chubsucker	Erimyzon oblongus						I	I
Northern hog sucker	Hypentelium nigricans			I	C	I	C	C
Smallmouth buffalo	Ictiobus bubalus			I				
Bigmouth buffalo	I. cyprinellus	I						
Spotted sucker	Minytrema melanops	C	C	C	C		I	C
Silver redhorse	Moxostoma anisurum				I		C	
River redhorse	M. carinatum	I	I	I	I	I		I
Black redhorse	M. duquesnei	I	C	C	C	I		
Golden redhorse	M. erythrurum	C	A	I	C	C		A
Shorthead redhorse	M. macrolepidotum			I	C			
Smallfin redhorse	M. robustum						C	
Bullhead catfishes								
Snail bullhead	Ictalurus brunneus						I	
White catfish	I. catus						I	
Yellow bullhead	I. natalis	I	I					I
Brown bullhead	I. nebulosus						C	

(Continued)

(Sheet 3 of 6)

Table E1 (Continued)

Common name	Scientific name	Tailwaters						
		Pine Creek	Gillham	Barren	Green	Beaver	Hartwell	Greeson
Bullhead catfishes cont.								
Flat bullhead	*I. platycephalus*						I	
Channel catfish	*I. punctatus*	C	C	I	I	I		I
Freckled madtom	*Noturus nocturnus*	I	I					
Flathead catfish	*Pylodictis olivaris*	I	C	I	I			I
Cavefishes								
Spring cavefish	*Chologaster agassizi*			I				
Pirate perches								
Pirate perch	*Aphredoderus sayanus*		I					I
Killifishes								
Northern studfish	*Fundulus catenatus*		I		I			
Blackspotted topminnow	*F. olivaceus*	C	C					C
Silversides								
Brook silverside	*Labidesthes sicculus*	C	C	I	I	A		I
Temperate basses								
White bass	*Morone chrysops*		I	I	I	A	I	
Yellow bass	*M. mississippiensis*	I	C					
Striped bass	*M. saxatilis*		I				I	

(Continued)

(Sheet 4 of 6)

Table E1 (Continued)

Common name	Scientific name	Tailwaters						
		Pine Creek	Gillham	Barren	Green	Beaver	Hartwell	Greeson
Sunfishes								
Rock bass	Amblioplites rupestris		I	I	C			
Redbreast sunfish	Lepomis auritus						A	
Green sunfish	L. cyanellus	C	A	I	I	I	C	A
Pumpkinseed	L. gibbosus						I	
Warmouth	L. gulosus	C	C	C	I		I	C
Orangespotted sunfish	L. humilis							I
Bluegill	L. macrochirus	A	A	C	C	C	C	A
Longear sunfish	L. megalotis	A	A	A	A	I		A
Redear sunfish	L. microlophus	C	C	I		I	I	I
Spotted sunfish	L. punctatus	I	I				I	
Smallmouth bass	Micropterus dolomieui		C	I	C			
Spotted bass	M. punctulatus	A	A	C	C	I		C
Largemouth bass	M. salmoides	C	C	I	I	I	C	C
White crappie	Pomoxis annularis	A	C	C	A	I		I
Black crappie	P. nigromaculatus	C	C	C		I		C
Perches								
Orangefin darter	Etheostoma bellum				I			
Greenside darter	E. blennioides	I			C			C
Rainbow darter	E. caeruleum			I	C			
Creole darter	E. collettei		I					C
Fantail darter	E. flabellare			I	I			
Harlequin darter	E. histrio		I					I
Stripetail darter	E. kennicotti				I			
Johnny darter	E. nigrum				I			
Orangebelly darter	E. radiosum		C					C
Orangethroat darter	E. spectabile		I	I				
Speckled darter	E. stigmaeum		I		I			I

(Continued)

(Sheet 5 of 6)

Table E1 (Concluded)

Common name	Scientific name	Tailwaters						
		Pine Creek	Gillham	Barren	Green	Beaver	Hartwell	Greeson
Perches cont.								
Banded darter	_E. zonale_			I	I			I
Yellow perch	_Perca flavescens_						C	
Logperch	_Percina caprodes_	C	C	I	C	A		C
Channel darter	_P. copelandi_	I	C		I			I
Gilt darter	_P. evides_				I			
Blackside darter	_P. maculata_		I		I			I
Blackbanded darter	_P. nigrofasciata_						I	
Leopard darter	_P. pantherina_		I					
Slenderhead darter	_P. phoxocephala_	I		I	I			
Dusky darter	_P. sciera_	I	C	I	I			
Sauger	_Stizostedion canadense_				I			
Walleye	_S. vitreum vitreum_				I	I	I	I
Drums								
Freshwater drum	_Aplodinotus grunniens_	I		I	I			I
Sculpins								
Mottled sculpin	_Cottus bairdi_					A		
Banded sculpin	_C. carolinae_			I	I	I		

(Sheet 6 of 6)

APPENDIX F: TEMPERATURE AND DISSOLVED OXYGEN PROFILES IN STUDY RESERVOIRS

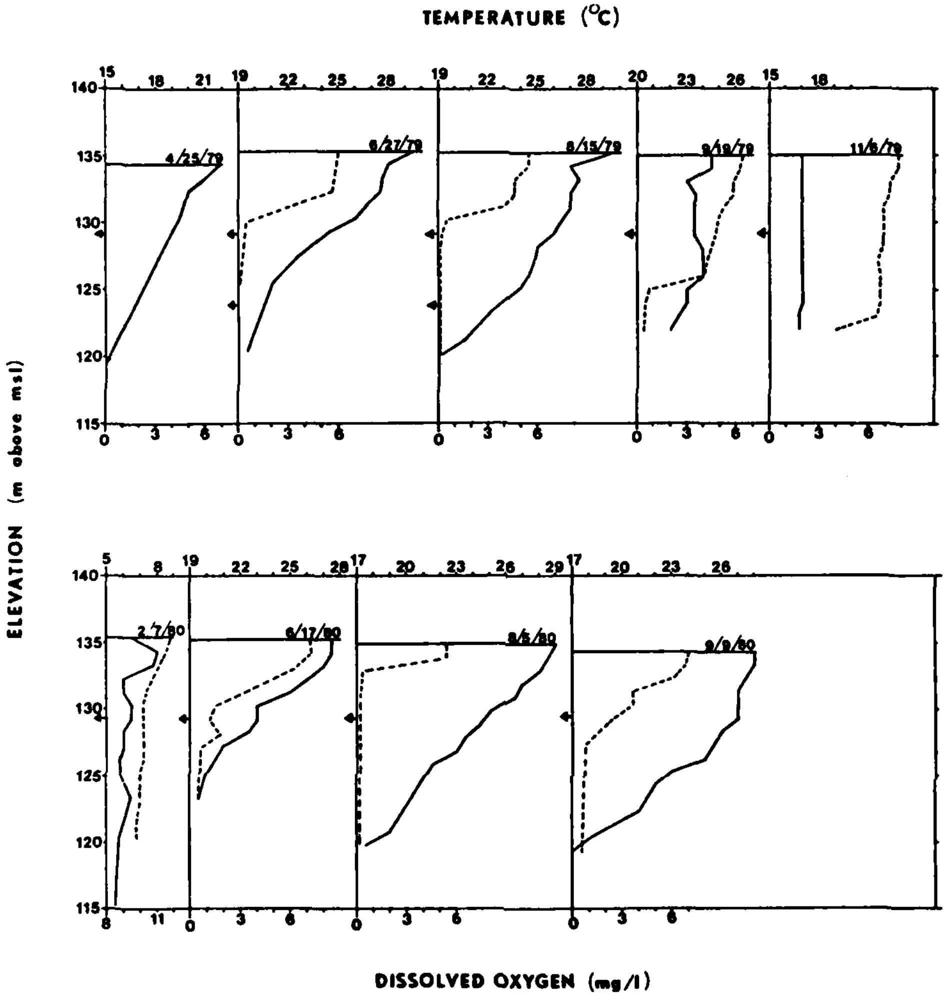

Figure F1. Temperature (solid line) and dissolved oxygen (dashed line) profiles for Pine Creek Lake in 1979 and 1980. Arrows indicate levels of water release from the reservoir on sample date

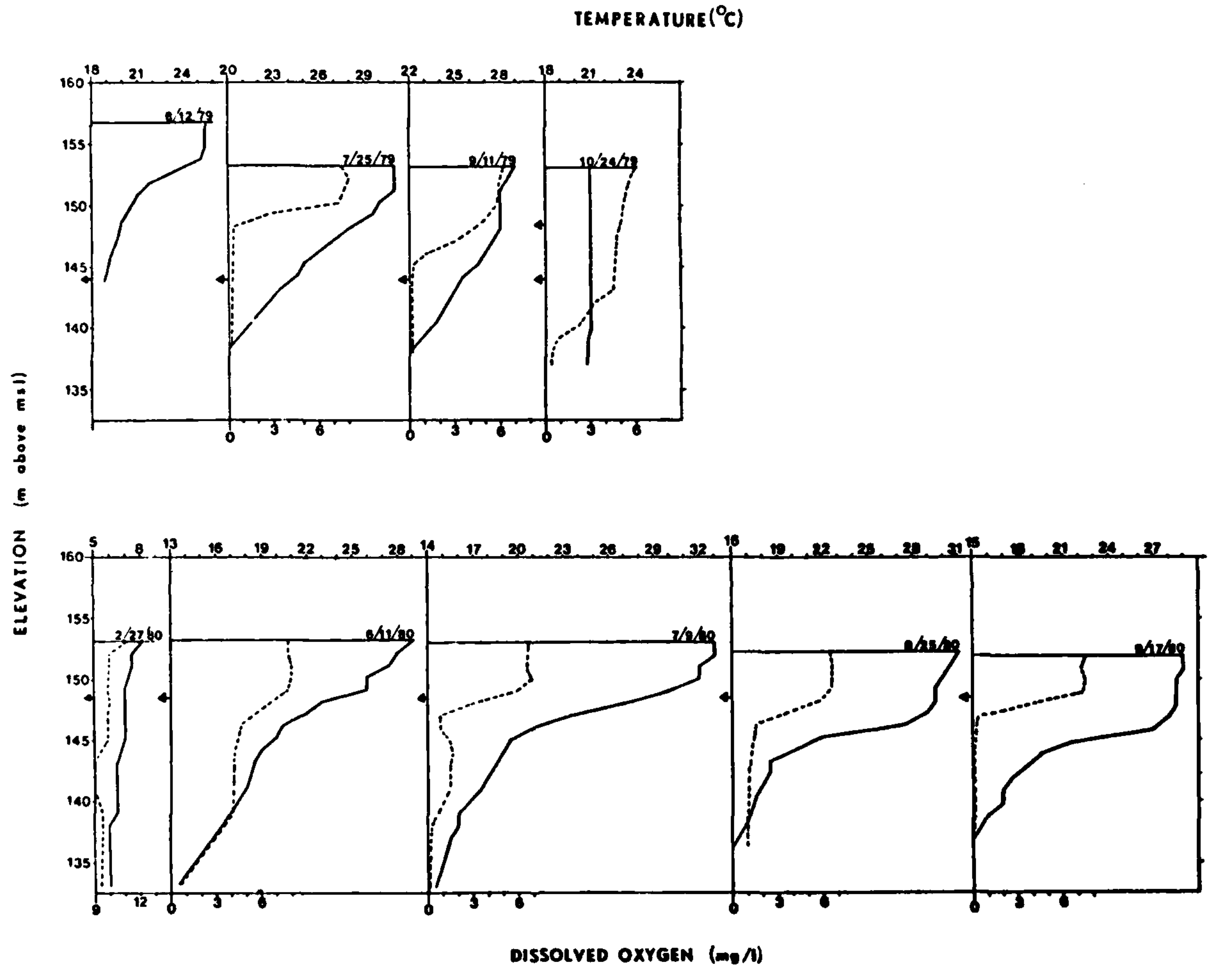

Figure F2. Temperature (solid line) and dissolved oxygen (dashed line) profiles for Gillham Lake in 1979 and 1980. Arrows indicate levels of water release from the reservoir on sample date

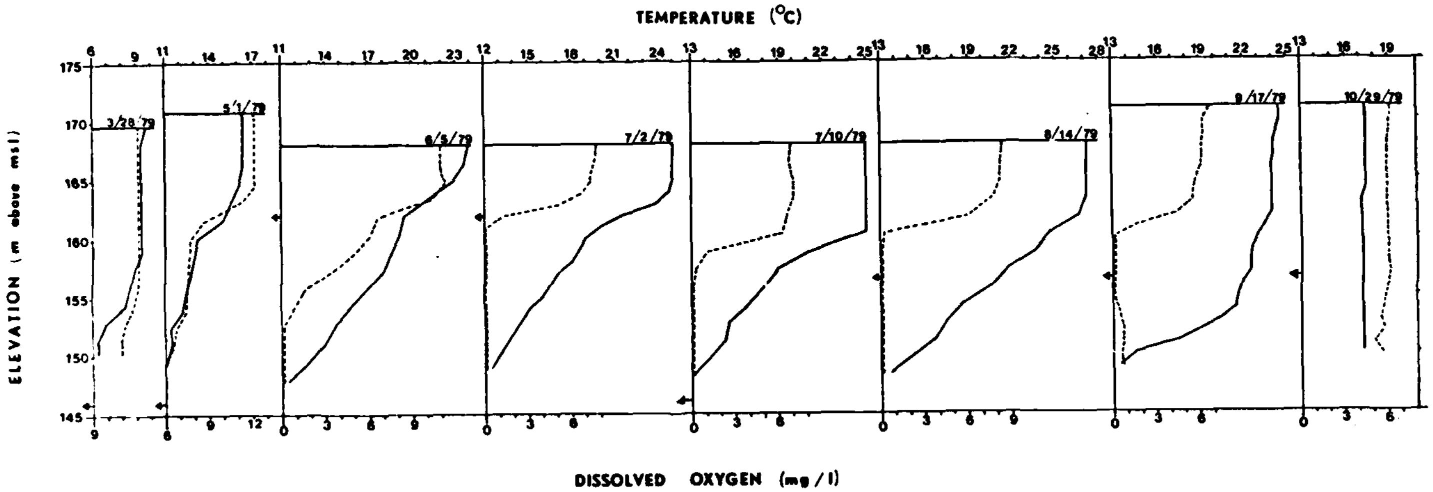

Figure F3. Temperature (solid line) and dissolved oxygen (dashed line) profiles for Barren River Lake in 1979. Arrows indicate levels of water release from the reservoir on sample date

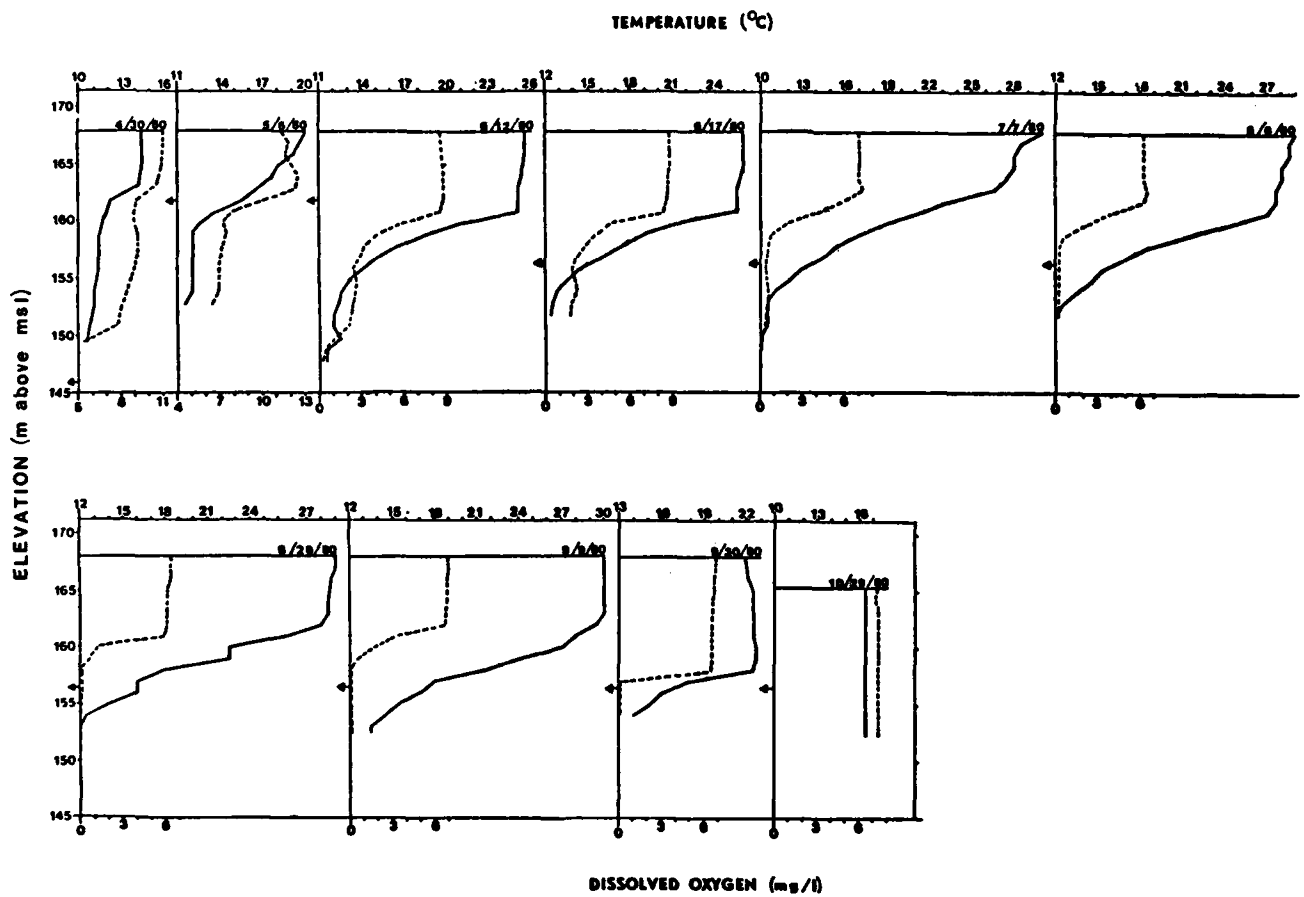

Figure F4. Temperature (solid line) and dissolved oxygen (dashed line) profiles for Barren River Lake in 1980. Arrows indicate levels of water release from the reservoir on sample date

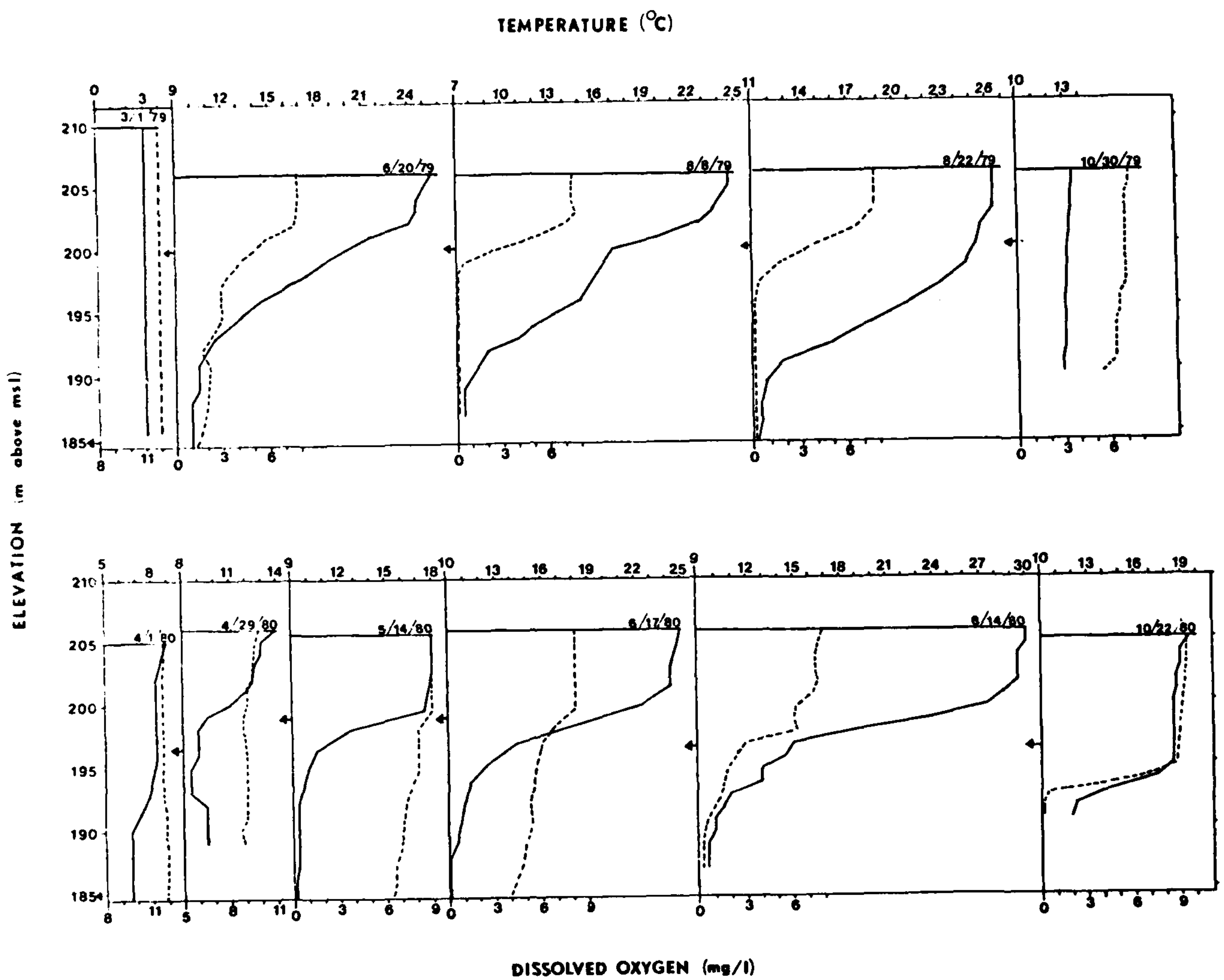

Figure F5. Temperature (solid line) and dissolved oxygen (dashed line) profiles for Green River Lake in 1979 and 1980. Arrows indicate levels of water release from the reservoir on sample date

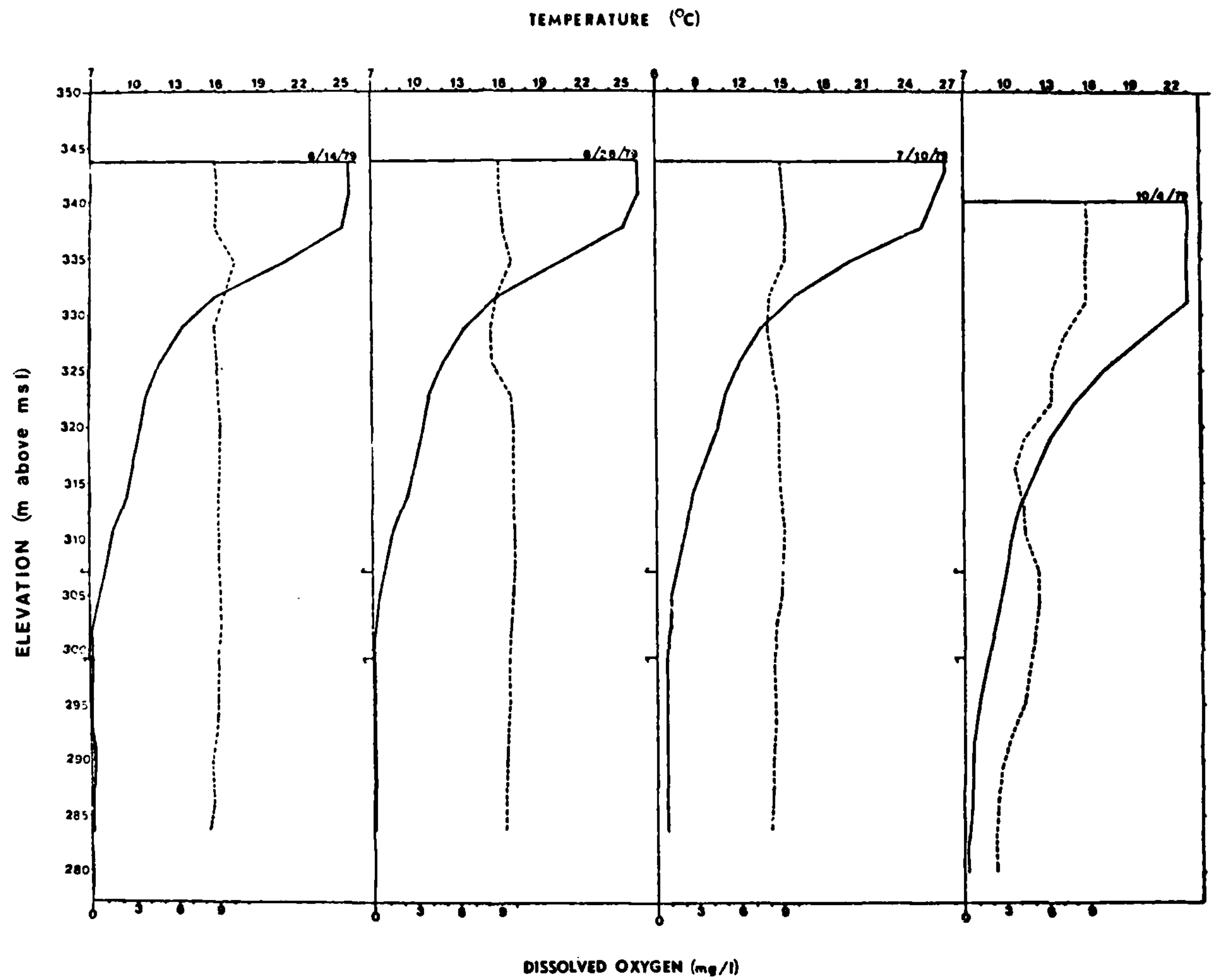

Figure F6. Temperature (solid line) and dissolved oxygen (dashed line) profiles for Beaver Lake in 1979. Arrows indicate depth range of water release through penstocks

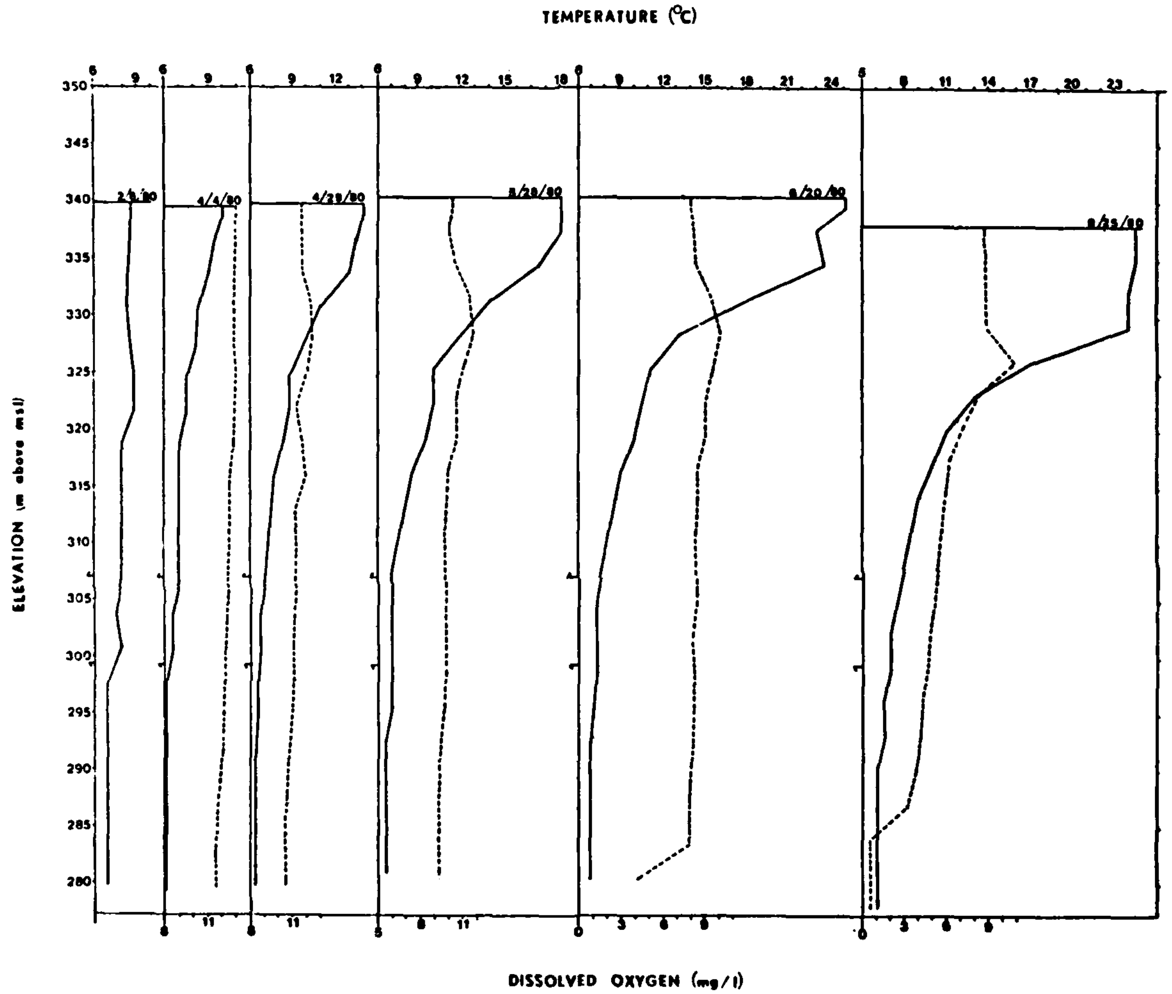

Figure F7. Temperature (solid line) and dissolved oxygen (dashed line) profiles for Beaver Lake in 1980. Arrows indicate depth range of water release through penstocks

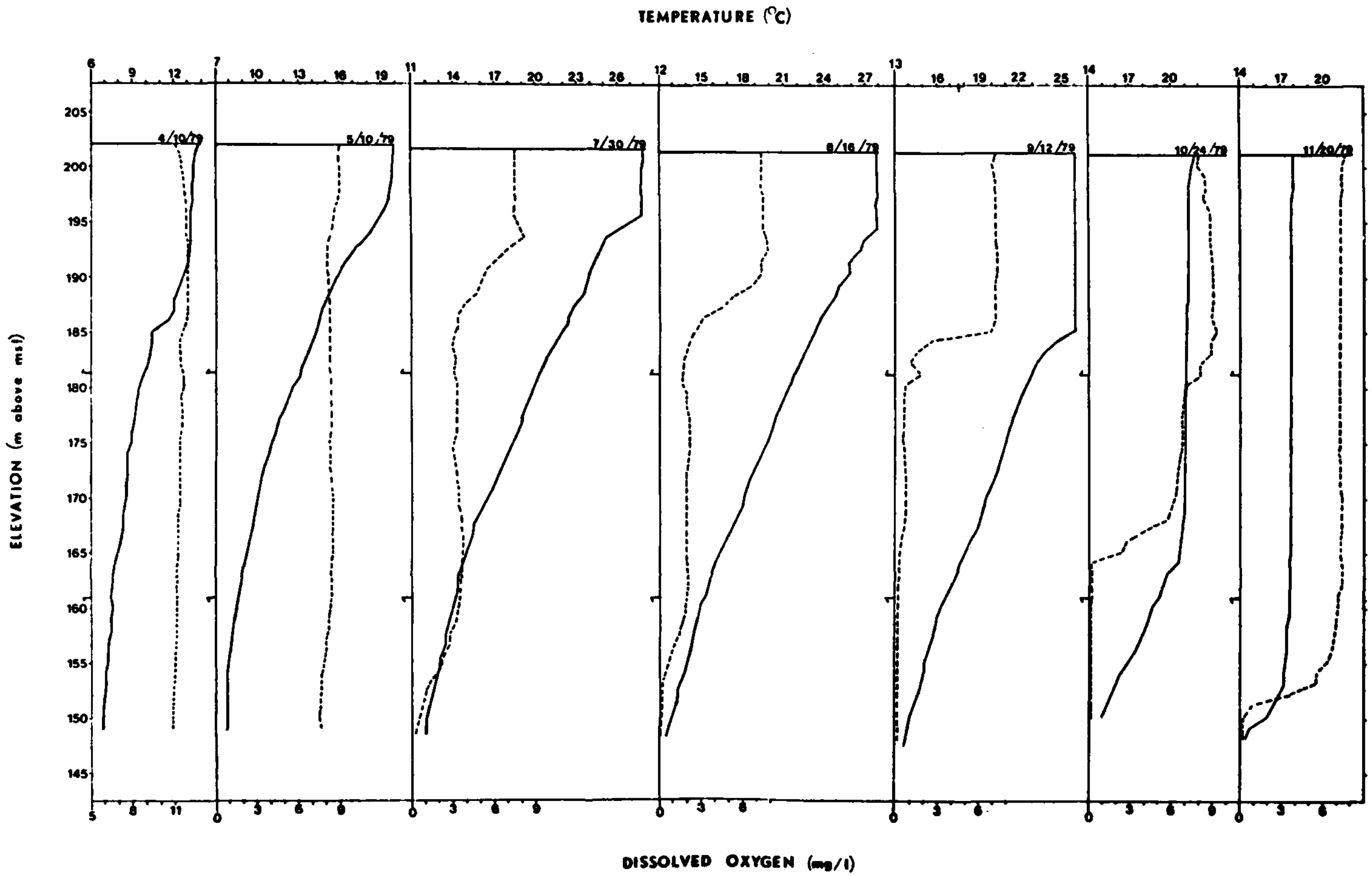

Figure F8. Temperature (solid line) and dissolved oxygen (dashed line) profiles for Hartwell Lake in 1979. Arrows indicate depth range of water release through penstock

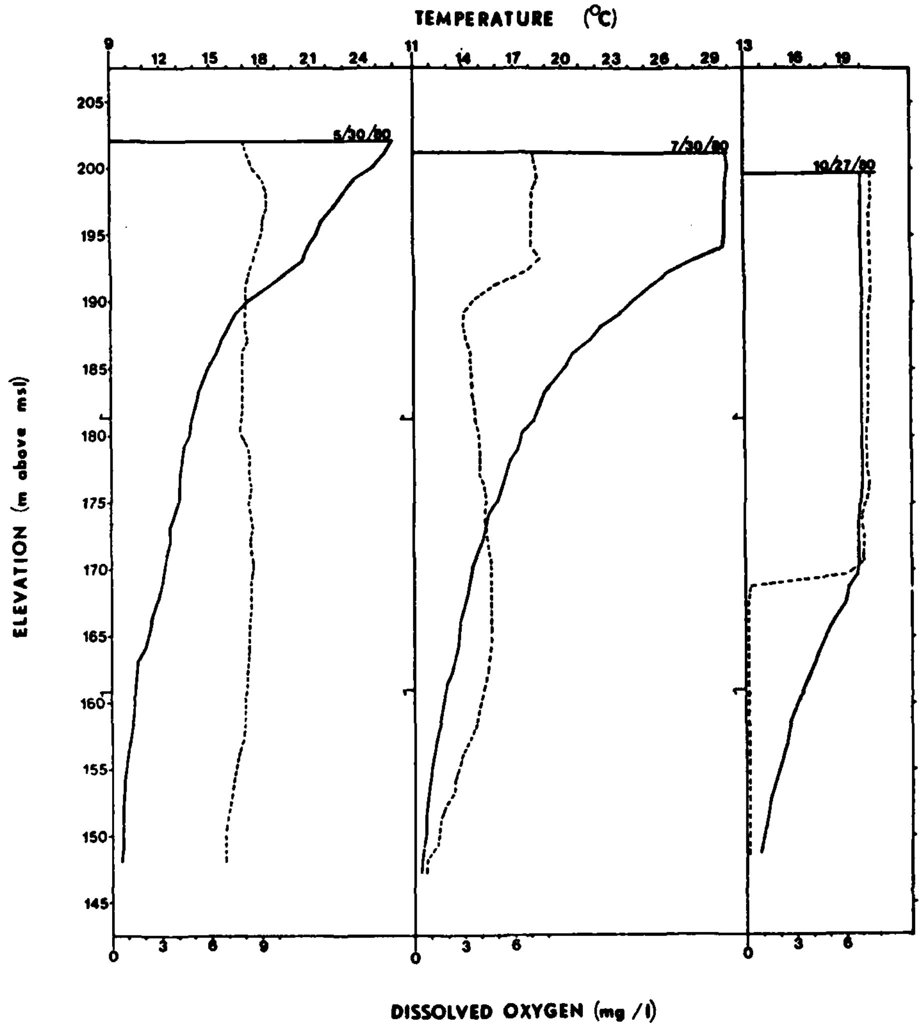

Figure F9. Temperature (solid line) and dissolved oxygen (dashed line) profiles for Hartwell Lake, 1980. Arrows indicate depth range of water release through penstocks

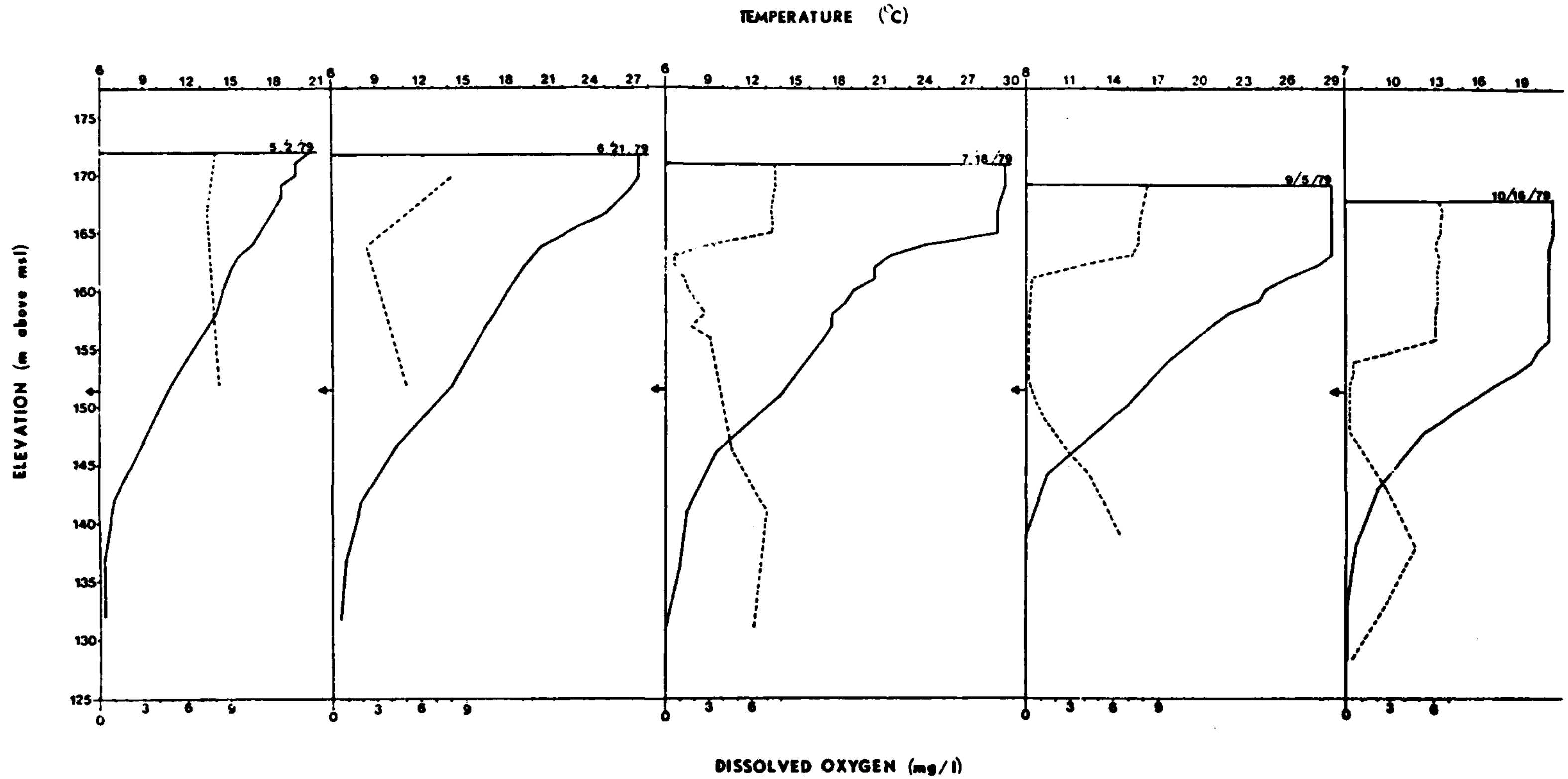

Figure F10. Temperature (solid line) and dissolved oxygen (dashed line) profiles for Lake Greeson in 1979. Arrows indicate depth of water release through penstocks

APPENDIX G: DAILY RESERVOIR RELEASES AND MAXIMUM WATER TEMPERATURES (WHERE AVAILABLE) IN THE SEVEN STUDY TAILWATERS, 1979 AND 1980

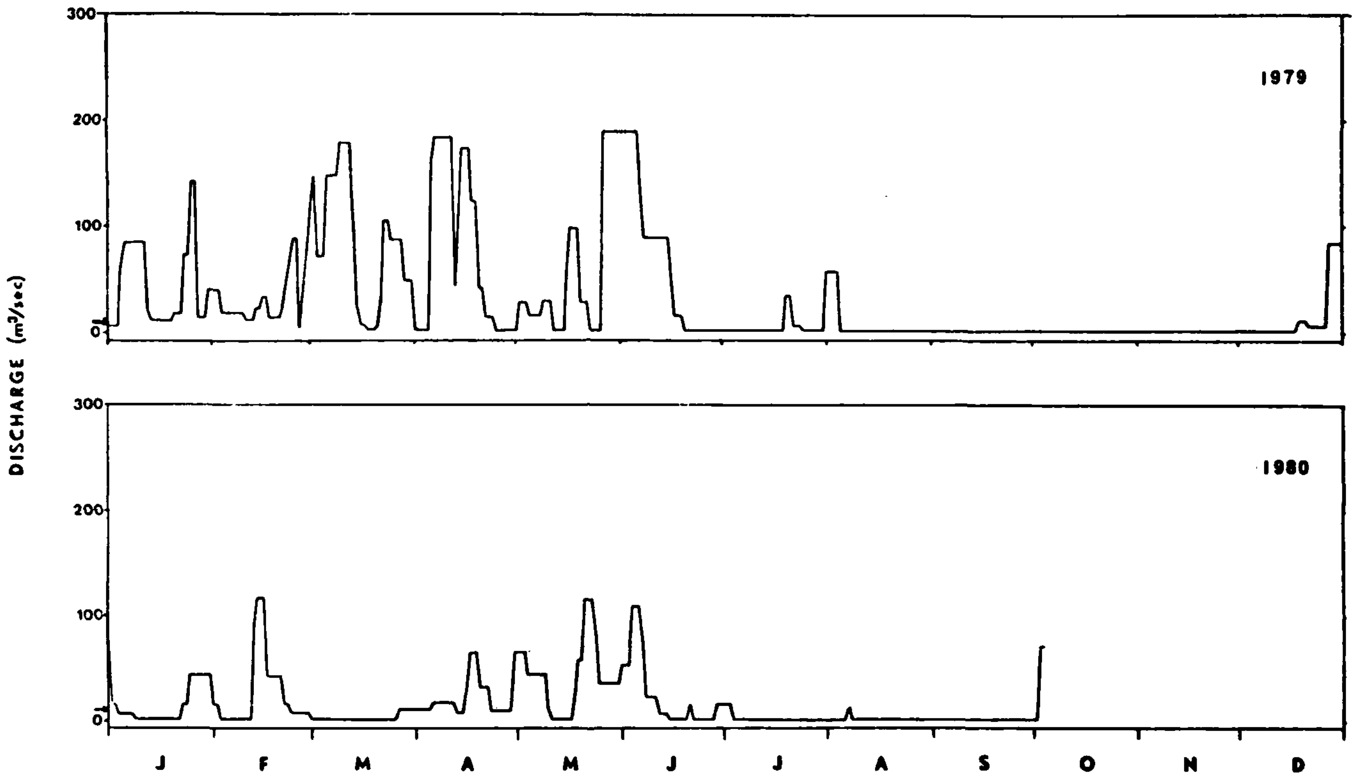

Figure G1. Mean daily flows in the tailwater below Pine Creek Lake in 1979 and 1980. Arrows indicate volume of maximum discharge through the bypass gates. (Data from CE discharge records)

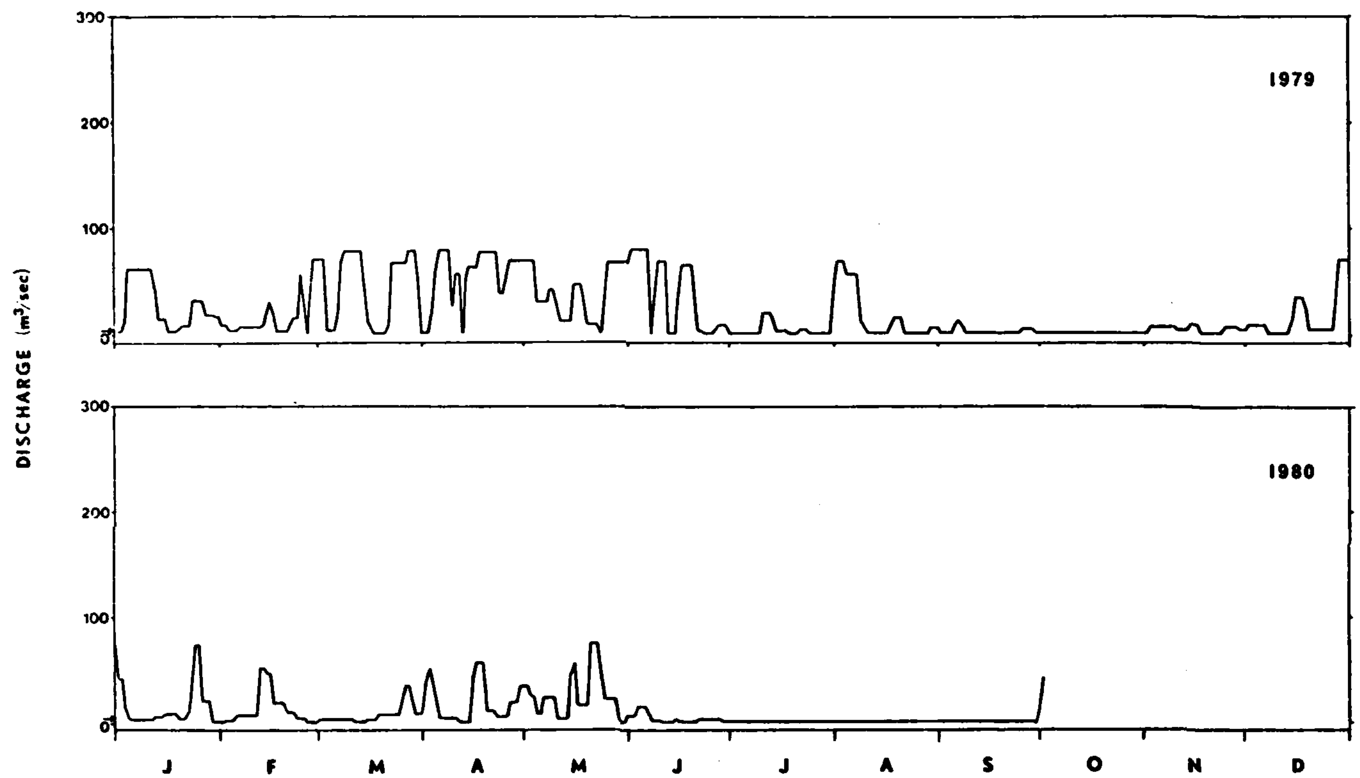

Figure G2. Mean daily flows in the tailwater below Gillham Lake in 1979 and 1980. Arrows indicate volume of maximum discharge through the bypass gates. (Data from CE discharge records)

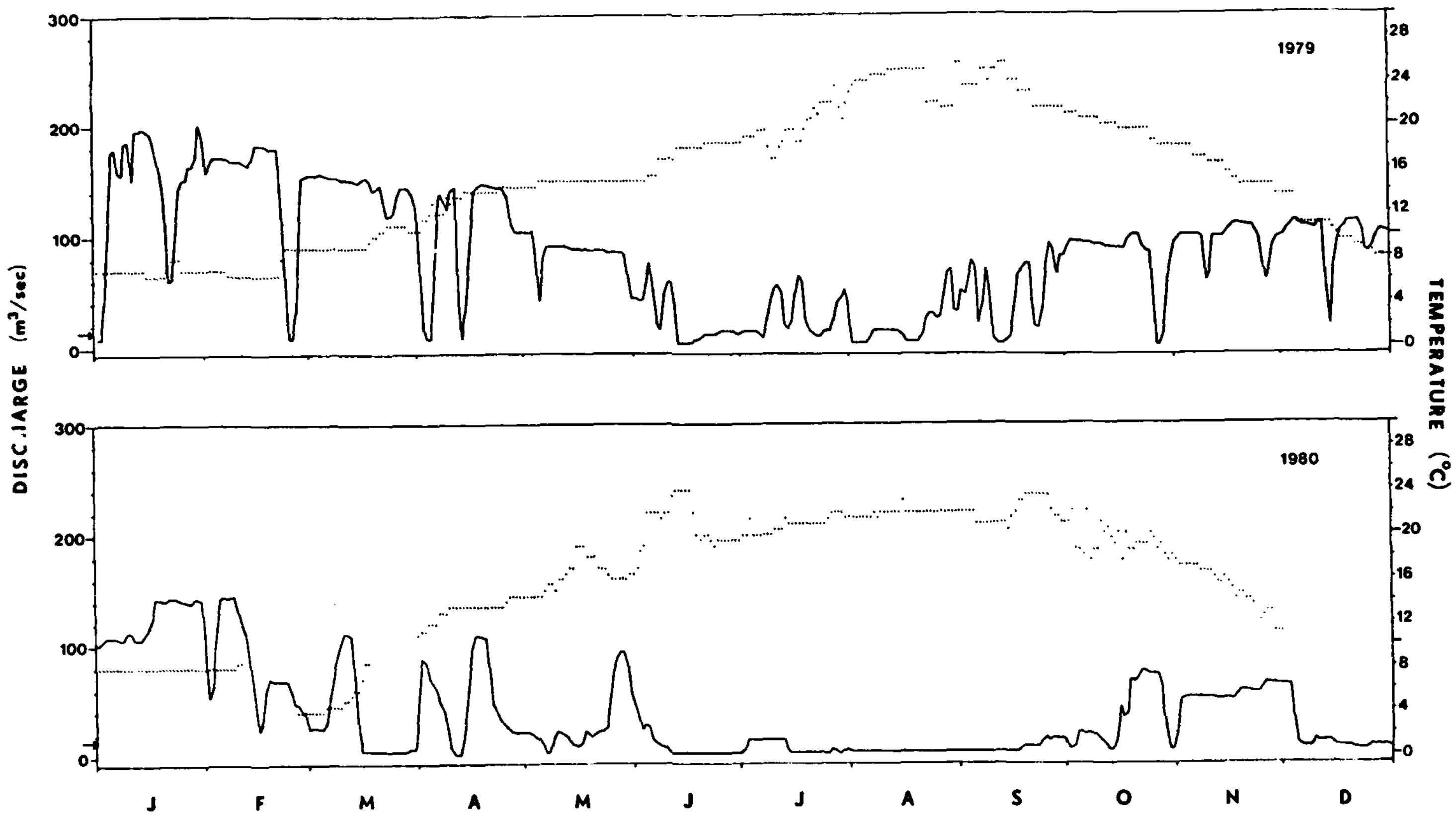

Figure G3. Mean daily flows (solid line) and maximum daily water temperatures (dotted line) in the tailwater below Barren River Lake in 1979 and 1980. Arrows indicate volume of maximum discharge through the bypass gates. (Data from USGC gauge station 0.8 km below dam)

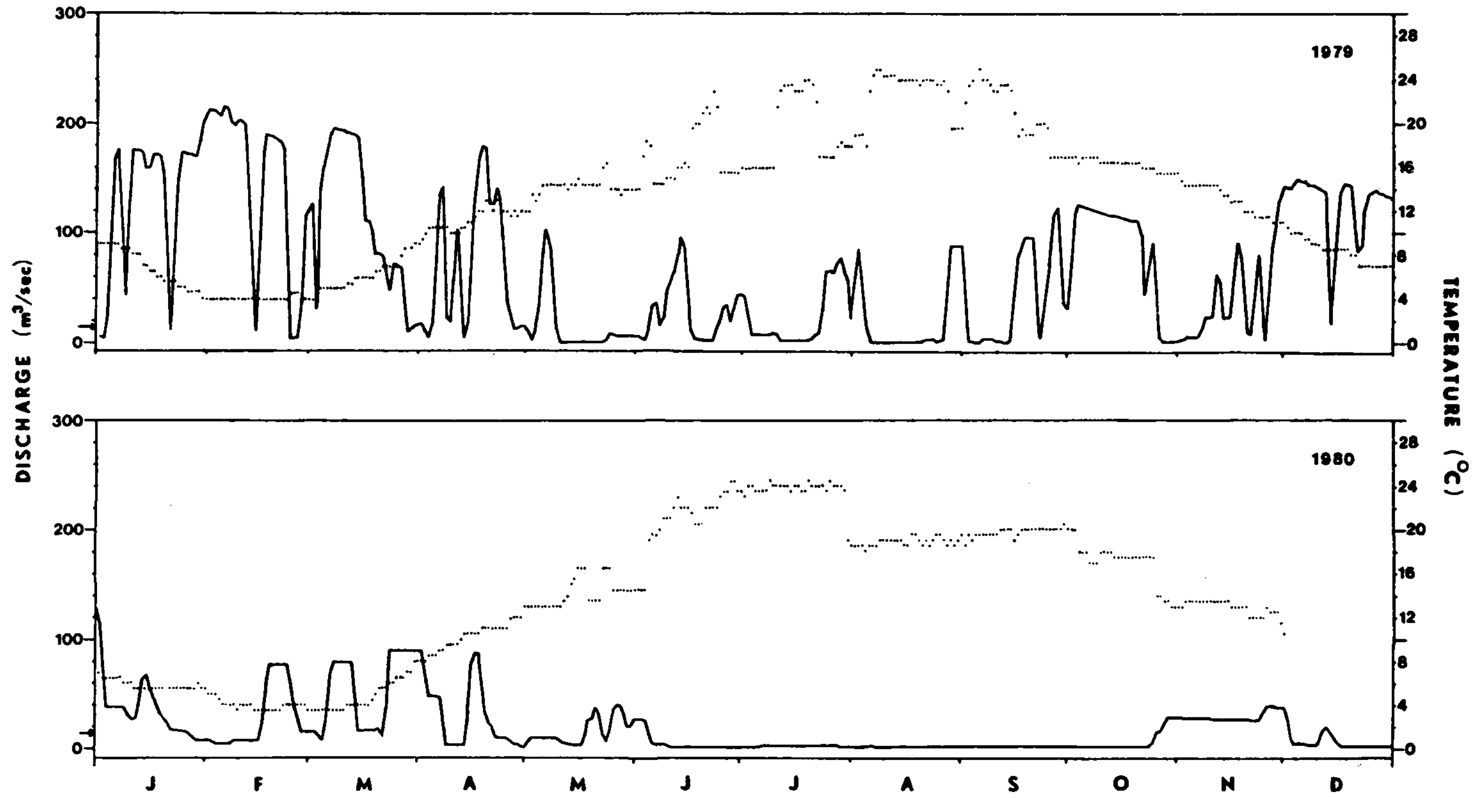

Figure G4. Mean daily flows (solid line) and maximum daily water temperatures (dotted line) in the tailwater below Green River Lake in 1979 and 1980. Arrows indicate volume of maximum discharge through the bypass gates. (Data from USGS gauge station 1.0 km below dam)

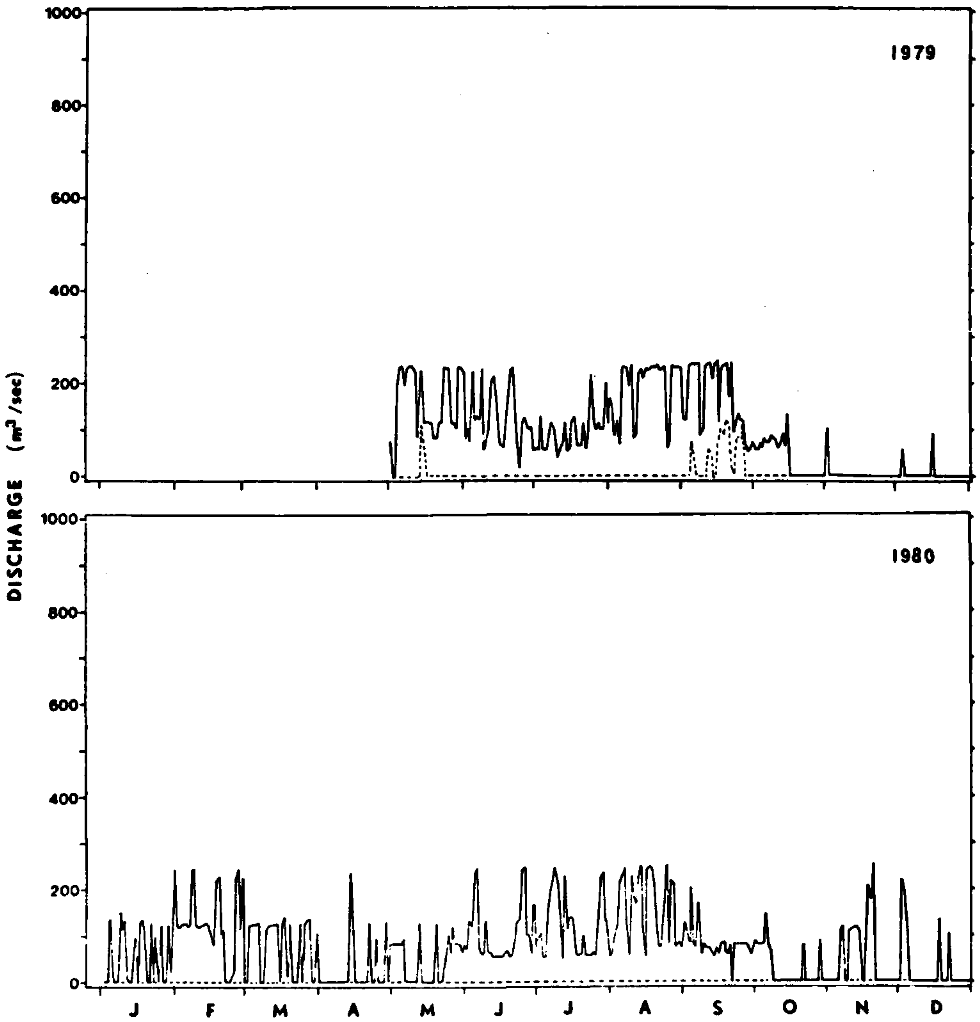

Figure G5. Daily maximum (solid line) and minimum (dashed line) releases from Beaver Lake in 1979 and 1980. (Data from CE discharge records)

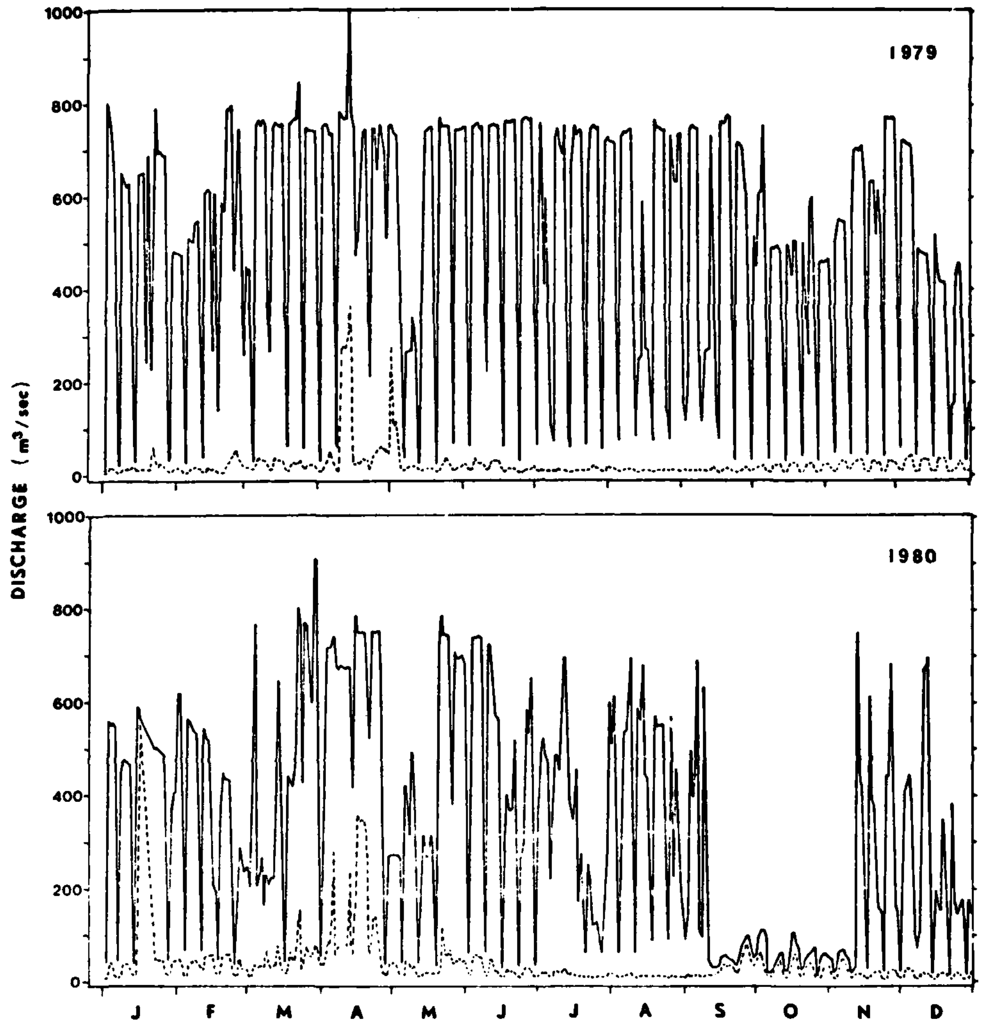

Figure G6. Daily maximum (solid line) and minimum (dashed line) flows in the tailwater below Hartwell Lake in 1979 and 1980. (Data from USGS gauge station 12.1 km below dam)

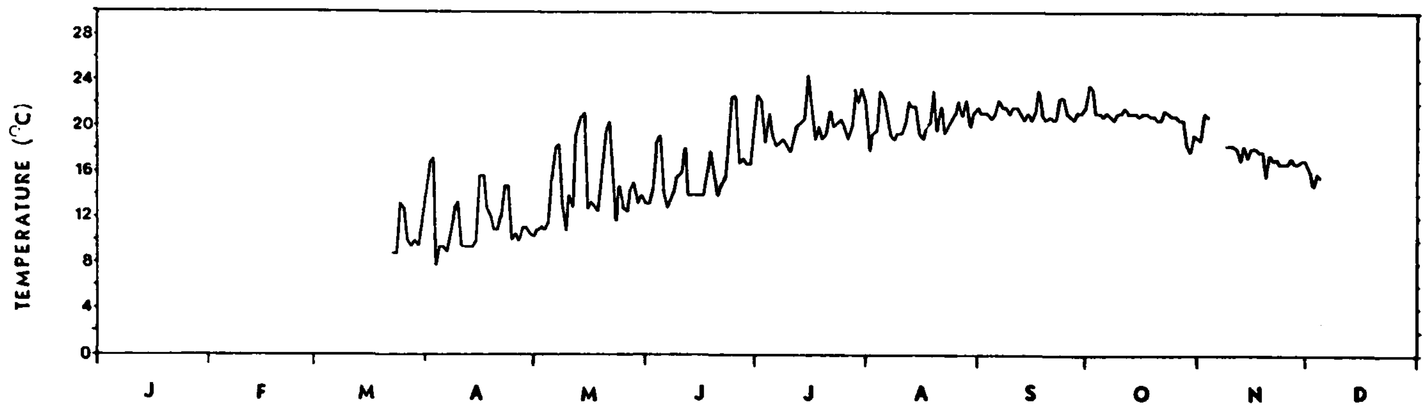

Figure G7. Maximum daily water temperatures in the tailwater below Hartwell Lake from March to December 1979. (Data from CE recorder 7.2 km below dam)

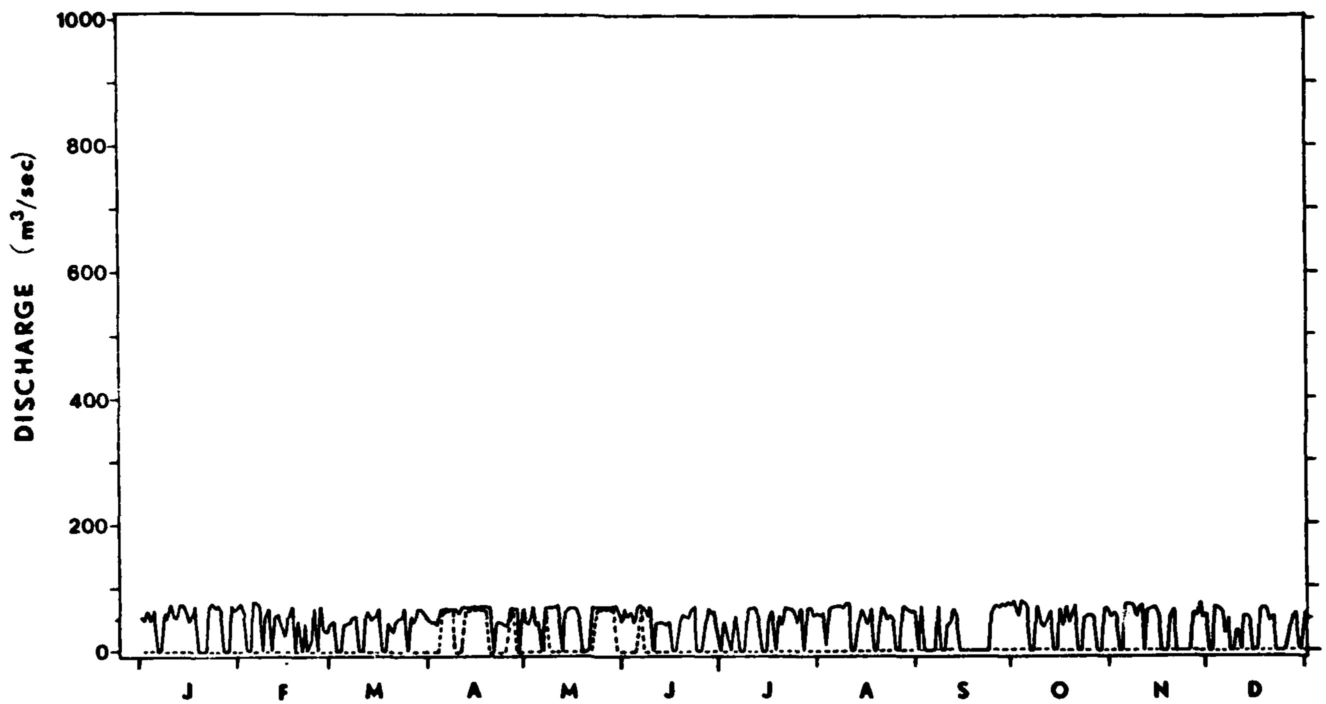

Figure G8. Daily maximum (solid line) and minimum (dashed line) releases from Lake Greeson in 1979. (Data estimated from CE operation reports)

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Effects of reservoir releases on water quality, macro-invertebrates, and fish in tailwaters : field study results / by Charles H. Walburg ... [et al.] (East Central Reservoir Investigations, National Reservoir Research Program, U.S. Fish and Wildlife Service). -- Vicksburg, Miss. : U.S. Army Engineer Waterways Experiment Station ; Springfield, Va. : available from NTIS, 1983.

176 p. in various pagings : ill. ; 27 cm. -- (Technical report ; E-83-6)

Cover title.

"February 1983."

Final report.

"Prepared for Office, Chief of Engineers, U.S. Army under EWQOS Task IIB."

"Monitored by Environmental Laboratory, U.S. Army Engineer Waterways Experiment Station."

At head of title: Environmental & Water Quality Operational Studies.

Bibliography: p. 108-109.

Effects of reservoir releases on water quality : ... 1983.
(Card 2)

1. Environmental impact analysis. 2. Fishes. 3. Invertebrates. 4. Reservoirs. 5. Water quality. I. Walburg, Charles H. II. United States. Army. Corps of Engineers. Office of the Chief of Engineers. III. National Reservoir Research Program. IV. Environmental & Water Quality Operational Studies. V. U.S. Army Engineer Waterways Experiment Station. Environmental Laboratory. VI. Title VII. Series: Technical report (U.S. Army Engineer Waterways Experiment Station) ; E-83-6.

TA7.W34 no.E-83-6

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